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THESIS

EARLY SYNTHETIC PROTOTYPING:
EXPLORING DESIGNS AND CONCEPTS
WITHIN GAMES

by

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December 2014

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13. ABSTRACT (maximum 200 words)

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We conducted a study asking: (1) What feedback can be gathered from game play? (2) Would that feedback be valuable?

To this end, groups of military officers were engaged in several scenarios to explore an unmanned vehicle concept called Robotic Wingman. Through the game sessions, players expressed ideas on the characteristics of a preferred interface and how to best employ Wingman.

Using a game environment to explore design concepts early in the acquisition process can be applied to early requirement refinement and rudimentary tradeoff analysis. The encouraging results of this preliminary work demonstrate a strong potential to leverage game environments to explore revolutionary concepts to efficiently and effectively shape the future of the Department of Defense.

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EARLY SYNTHETIC PROTOTYPING: EXPLORING DESIGNS AND CONCEPTS WITHIN GAMES

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LIST OF ACRONYMS AND ABBREVIATIONS

2D	two dimensional
3D	three dimensional
AAR	after action review (alternate: report)
AI	artificial intelligence
AK	Avtomat Kalashnikov
ARCIC	Army Capabilities Integration Center
ASD(R&E)	Assistant Secretary of Defense for Research and Engineering
APD	autonomous platform demonstrator
BLUFOR	Blue (friendly) forces
CAC	common access card
CDD	Capability Development Document
CJCS	Chairman of the Joint Chiefs of Staff
COA	course of action
CONOP	concept of operations
CPD	Capability Production Document
DAG	Defense Acquisition Guidebook
DAS	Defense Acquisition System
DAU	Defense Acquisition University
DOD	Department of Defense
DIS	distributed interactive simulation
DOTMLPF-P	doctrine, organization, training, materiel, leadership, personnel, facilities, and policy
DSMC	Defense Systems Management College
EASE	Executable Architecture Systems Engineering
EMD	Engineering and Manufacturing Development
ERS	Engineering Resilient Systems
ESA	Entertainment Software Association
ESP	Early Synthetic Prototyping
FACT	Framework for Assessing Cost and Technology
FOC	full operational capability
FRP	full rate production

FY	fiscal year
GAO	Government Accountability Office
GBU	guided bomb unit
HMMWV	high mobility multi-purpose wheeled vehicle
ICD	Initial Capabilities Document
IOC	initial operational capability
JCIDS	Joint Capabilities Integration Development System
KIA	killed in action
LRIP	low rate initial production
M&S	modeling and simulation
MDAP	major defense acquisition program
MDD	material development decision
MMOG	massively multi-player online game
MOVES	Modeling, Virtual Environments, and Simulations Institute
MSA	Materiel Solution Analysis
NVG	night vision goggles
O&S	Operations and Support
OUSD(AT&L)	Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics
OPFOR	opposing (enemy) forces
P&D	Production and Deployment
PAUC	program acquisition unit cost
PC	personal computer
PDR	preliminary design review
POM	Program Objective Memorandum
PPBE	Planning, Programming, Budgeting, and Execution
QDR	*Quadrennial Defense Review*

R&D	research and development
RAND	Research and Development Corporation
RDT&E	research, development, test, and evaluation
S&T	science and technology
SBA	Simulation-Based Acquisition
SBD	Scenario-Based Design
SMART	Simulation and Modeling for Acquisition, Requirements, and Training
SE	synthetic environment
SE	Systems Engineering
SE 2025	Systems Engineering 2025
SEA	Synthetic Environments for Assessment
SME	subject matter expert
TARDEC	Army Tank and Automotive Research, Development, and Engineering Center
TD	Technology Development
TRL	Technology Readiness Level
UAS	unmanned aircraft system
UGV	unmanned ground vehicle
USD(AT&L)	Under Secretary of Defense for Acquisition, Technology, and Logistics
UTACCS	Unmanned Tactical Autonomous Control and Collaboration System
VBIED	vehicle borne improvised explosive device
VBS2/3	Virtual Battlespace Simulation Version 2 or 3
VE	virtual environment
VOIP	voice over internet protocol
WIA	wounded in action
WSARA	Weapons System Acquisition Reform Act of 2009
XML	extensible markup language

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EXECUTIVE SUMMARY

The use of modeling and simulation in acquisition can effectively support the acquisition of new military technologies. Rather than limit input on proposed system requirements and capabilities to those of leaders in a program office, or experienced science and technology representatives, Early Synthetic Prototyping (ESP) will bring in input from warfighters to develop future systems. A distributed game environment can be leveraged as an effective medium to bring warfighters into the development process.

ESP is a process and set of tools that enables warfighters to inform technology development and acquisition decisions by assessing emerging technologies in a game environment. Collaborators in acquisition, science and technology, and industry can develop models and scenarios for play and assessment. ESP allows an unbounded increase in potentially disruptive ideas to be explored at minimal cost by inviting warfighters at all levels to drive, define, and refine future systems.

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I. INTRODUCTION

The decisive edge embodied in the United States military is sustained, in part, by the continual pursuit and dominance in technological innovation for military applications. The secretary of defense, the Honorable Chuck Hagel, stated, "A world where our military lacks a decisive edge would be less stable [and] less secure for both the United States and our Allies" (Parker, 2014, para. 12). The United States military has historically employed its technologically superior resources to a decisive advantage against its adversaries. Modern antagonists range from technological peers to developing nations and non-state actors. More nimble states that are less encumbered by bureaucratic institutions have a distinct advantage in the trajectory at which advancement can occur despite a clear disadvantage in available resources.

A. REQUIREMENTS FOR TECHNOLOGICAL SUPERIORITY

In a cautionary message supporting proposed improvements to the acquisition process, the Honorable Frank Kendall, under secretary of defense for acquisition, technology, and logistics (USD[AT&L]) recently warned that "our technological superiority is very much at risk" (Freedberg, 2014, para. 1). The ongoing effort to seek innovative technological solutions for current and future problems must include the Department of Defense (DOD), science and technology (S&T), and industry to keep ahead of any adversary posing a threat, whether that be a first-world peer or a less sophisticated entrant.

To maintain superiority in the face of a nimble opposition, the DOD must foster the development and procurement of technology to

- remain agile,

- explore a multitude of options through prototyping,[1] and

- conduct appropriate and meaningful evaluation of options.

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[1] As discussed in Chapter II, Section B, this thesis takes a broad view of "prototyping" that includes both conventional physical prototypes as well as virtual prototypes of varying fidelity throughout the acquisition pipeline.

In meeting these requirements, the DOD will be able to achieve and maintain technological superiority through the development and procurement of the systems deemed necessary to meet warfighter needs, now and in the future. With the assumption that these three specific areas of interest are necessary to support advancing technological superiority, the DOD must develop a new means to identify, prototype, and assess emerging technologies, ideas, and concepts. This thesis is based on an assumption that traditional acquisition, while important, is inadequate to meet this emerging need. The DOD acquisition process needs something new that expands the role of our most important asset: the warfighter.

A distributed game environment is proposed as a promising collaborative venue for reliable evaluation of future concepts. Secretary Hagel supported the ability to "assess which commercial innovations have military potential … rapidly adopt them and adapt them, then test and refine them, including through war-gaming and demonstrations" (Lyle, 2014, para. 25). This effort can be accomplished for commercial innovations, proposed military systems, and the necessary mission context for those systems within the game environment proposed for Early Synthetic Prototyping (ESP).

B.   EARLY SYNTHETIC PROTOTYPING: AN ENVIRONMENT TO FOSTER INNOVATION

ESP is a process and set of tools proposed by the Army Capabilities Integration Center (ARCIC) Army Capabilities as a means to aid innovation. More importantly, ESP will bring in warfighters as a source of creativity and assessment. ESP proposes a distributed game network where virtual (or synthetic) prototypes can be quickly built and tested in realistic scenarios. Warfighters can "play" the prototypes in the scenarios and also introduce modifications for new prototypes or concepts. The output is notional performance data of the prototypes for assessment and further application to system development. The ESP concept is described in detail in Chapter 3.

To attain the best system solution, ESP looks beyond the traditional program acquisition unit cost (PAUC), which is the program acquisition cost divided by the quantity procured (Defense Acquisition University, 2014a). ESP aims to increase the

value of each unit rather than strictly reduce the numerator, which encompasses the total cost of the development and acquisition effort. With ESP, the DOD will get the best possible systems to warfighters, thereby improving overall value of the system. Presumably, if the right system is developed and procured, it has the potential to save lives or support successful engagements. Therefore, the high value system can reduce the need for additional or replacement systems to accomplish the same mission over an extended duration.

In a distributed game environment, ESP offers the opportunity to develop synthetic prototype solutions rapidly and push them out for collaboration and evaluation within weeks or days, rather than months or years. Instead of limiting the number of prototypes or options to be considered based on cost or available time, ESP creates an environment for unbounded development opportunities. Major defense acquisition programs (MDAPs), historical and recent, demonstrate how the evaluation of full-scale physical prototypes can carry considerable cost in funding and time. For example, in the video titled "Battle of the X-planes," the quantity of physical prototypes to be evaluated was limited to two competitors (Nova, 2003). More recently, the Joint Light Tactical Vehicle evaluated three competing prototypes that cost more than $177 million and 27 months (Fast, 2014). The Littoral Combat Ship effort assessed prototypes from two competitors expending over $1 billion and 72 months (Fast, 2014). In contrast to these MDAPs, future programs can employ ESP to substantially increase the number of prototypes to be evaluated early in the process and in a cost-effective virtual environment. Synthetic prototypes can also be virtually run through multiple scenarios for additional simulated evaluation in variant conditions and environments without the cost of bent metal or a live exercise or war game.

Within ESP, the community available to contribute to a reliable evaluation of proposed technology solutions is nearly unbounded. Furthermore, this community can bring a previously untapped breadth and depth of experience to offer realistic and experienced perspective on how a proposed system could be best employed. Within the DOD, services can work collaboratively to develop a bevy of proposed solutions and collect notional performance data in fixed scenarios, recommendations for system

modification and resulting performance changes, and concepts for system employment and tactics beyond existing scenarios. The evaluators in ESP are not limited to professionals in S&T or acquisition, but rather are open to the warfighters with the tactical and operational experience to provide valid input to develop and refine proposed system solutions.

C.   EARLY SYNTHETIC PROTOTYPING: THE VALUE PROPOSITION OF THIS THESIS

ESP can be successful only if the assessment component is trusted and reliable. It is not enough that warfighters can "play" with virtual prototypes early in the design process if researchers are unable to learn anything useful that can be put to immediate use to improve the acquisition program or concept. Therefore, this thesis is focused on how to assess prototypes in a distributed game network: What feedback can be gleaned, and is it useful to decision-makers?

Systems are developed and acquired within the DOD Decision Support Framework, and ESP will become an additional option within this existing construct. Prototyping has already been incorporated as a useful tool and is mandated in some cases. Simulation efforts within acquisition are not new, and ESP can gain valuable insight from previous efforts. To make ESP viable, a large number of contributors is essential. Game analytic techniques should prove useful in collecting and evaluating the data accumulated from warfighter game play for evaluation and digestion by decision-makers.

This thesis reports on a study undertaken at the Naval Postgraduate School to explore whether a distributed game environment is an appropriate venue to conduct a reliable evaluation. Furthermore, we investigated the forms that assessment data might take, yielding insights to the next steps in determining how game analytics and other techniques might be used to seamlessly and unobtrusively collect assessment data from game players, which could guide future acquisitions.

In summary, the hypothesis of ESP is that value, rapid development, consideration of multiple options, and the conducting of reliable evaluation are necessary to achieve and maintain technological superiority. This thesis explores one portion of that

premise, arguing that reliable assessments can be accomplished through the accumulation of warfighter input through game play of proposed systems in a synthetic environment.

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II.   BACKGROUND

Early Synthetic Prototyping touches multiple facets of system development, starting with the acquisition framework itself. Within the acquisition umbrella, ESP will have multiple stakeholders: users, designers, modeling and simulation professionals, and science and technology representatives. ESP will use a game environment to interact with these stakeholders, so the ability to collect, process, and disseminate useful data is essential to making the warfighter accessible game environment a useful tool for decision-makers.

A.   ACQUISITION

Acquisition programs in all uniformed services struggle to meet prescribed timelines, remain within budget, and retain the agility needed to meet looming, but unknown, requirement changes. The DOD budget request for fiscal year (FY) 2012 totaled over $553 billion; over $203 billion of that total was designated for procurement and research, development, test, and evaluation (RDT&E) programs (Office of the Secretary of Defense [Comptroller], 2011). Following a decade of persistent combat necessitating high expenditures, the future DOD budget will be significantly reduced (Under Secretary of Defense for Acquisition, Technology, and Logistics [USD(AT&L)], 2014). This reduction makes prioritizing efficiency an imperative for acquisition. Of note, the president's FY2015 budget, seen in Figure 1, shows that procurement and RDT&E combined will fall to $153.9 billion, meaning that S&T experts must continue to develop solutions with a smaller budget (USD[AT&L], 2014). See Appendix A for additional historical budget data.

by Budget Account

- MilCon $5.4
- Other $2.4
- RDT&E $63.5
- MilPer $135.2
- Procurement $90.4
- O&M $198.7

by Military Department

- Defense Wide $89.8
- Navy $147.7
- Army $120.3
- Air Force $137.8

NOTE: Budget amounts are in billions of then-year (unadjusted) dollars. OCO is not included. "MilCon" is Military Construction.
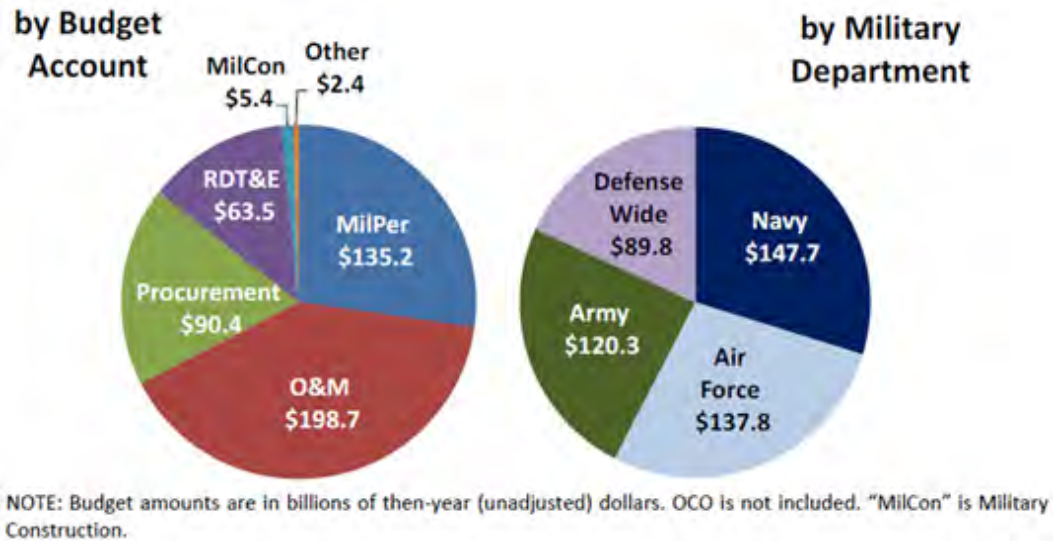
Figure 1.   2015 DOD Budget Breakout (from USD[AT&L], 2014)

Anecdotally, warfighters report that it takes too long to develop and acquire technology solutions for the military and, upon receipt, system capabilities might be exceeded by those of products procured commercially off the shelf for lower cost. The Government Accountability Office (GAO) report on Defense Acquisition (2012) backs up that anecdotal data, revealing that for 96 major acquisition programs in place in FY2011, total acquisition costs exceeded estimates by over $74.4 billion (GAO, 2012). Research and development costs contributed $14 billion to that total overage. The GAO report further noted that over the course of FY2011, the average delay of in-progress programs increased by one month; this brings the overall average delay to 23 months when compared to a program's initial full estimate (2012). Programs contributing to the $14 billion increase in research and development costs were found to be in production or using concurrent development and production strategies. Justifications for the cost increases ranged across the following: "reduce risk," "meet requirements," "modernization," "correction of deficiencies," "new capabilities and testing," and "software development" (GAO, 2012, p. 10).

Given the nature of the reported cost increases, the additional requirements identified in FY2011 may have been anticipated and avoided through the conducting of a more thorough requirements analysis prior to declaration of cost and time estimates based

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on acquisition strategies. The ability to clearly identify requirements and all associated costs is critical to a successful acquisition strategy, but defense programs are challenged by the need to predict the unpredictable at an early stage in the acquisition cycle.

1.   Department of Defense Decision Support System

The DOD Decision Support System, represented in Figure 2, also referred to as the Big "A" concept, can be a complicated process to navigate. The process map for the Decision Support System is notoriously complex and derisively referred to the "horse blanket" (Defense Acquisition Portal, 2010). The level of detail required to successfully take a program of record from the "great idea" stage through fielding and employment and then to eventual retirement requires a knowledgeable and experienced team of acquisition professionals. The proposal for ESP in no way seeks to add a mandatory event for program managers within the already lengthy list of to-do requirements that must be fulfilled for any MDAP. Rather, ESP is a supplementary tool to be used within the acquisition framework to support the effort of a service or program to refine and develop the best possible system to support the warfighter.
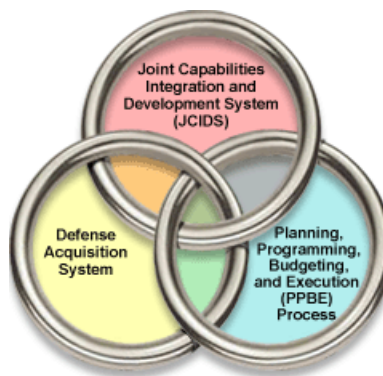
Figure 2.   Abstraction of the DOD Decision Support System, also Known as
the Big "A" (from Defense Acquisition University [DAU], 2014a)

The Big "A" framework shown in Figure 2 is not limited to the Defense Acquisition System (DAS). The DAS is one of three interdependent decision support systems, with the others being the Joint Capabilities Integration and Development System (JCIDS) and the Planning, Programming, Budgeting, and Execution (PPBE) process. JCIDS supports the

Joint Requirements Oversight Council (JROC) and the Chairman of the Joint Chiefs of Staff (CJCS) and focuses on identifying warfighting capability gaps that could be filled by either a materiel solution or non-materiel change to the doctrine, organization, training, leadership, personnel, facilities, or policy (DOTMLPF-P). JCIDS, therefore, informs the decision on solutions, materiel or otherwise, needed in support of a particular capability and seeks to effectively identify, assess, validate, and prioritize joint capability requirements. Where non-materiel solutions are insufficient, the DAS is called into play to identify and procure an effective materiel solution to offset the gap in capability. Figure 3 shows the interaction between the JCIDS and the DAS and the points at which JCIDS documents are incorporated in the DAS process. The PPBE system completes the triad by resourcing the requirements determined in the JCIDS and DAS in conjunction with the mandates of the president's National Security Strategy. PPBE is the process by which activities output from the JCIDS and DAS are funded for development, fielding, and sustainment, as well as prioritization against other requirements (Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics [OUSD(AT&L)], 2013).
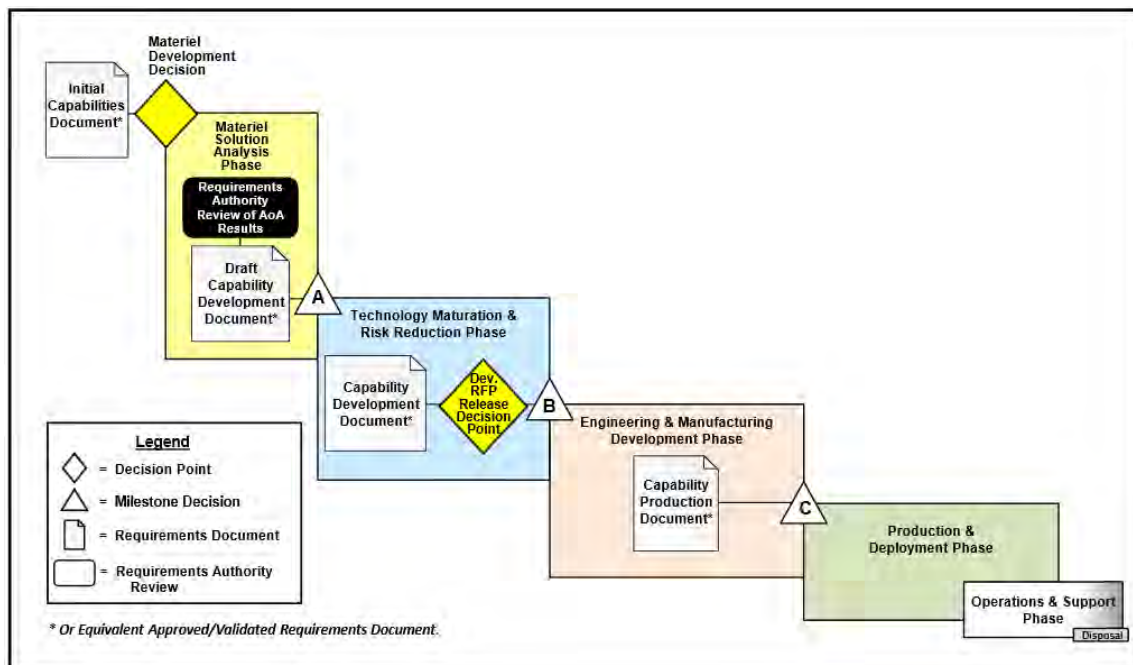
Figure 3.   Interaction Between the Capability Requirements Process and the Acquisition Process (from OUSD[AT&L], 2013, p. 5).

2. Joint Capabilities Integration Development System

JCIDS documents are integrated into the phases of acquisition as a linkage from the capability requirement, as seen in Figure 3. The five phases of the DAS are Materiel Solution Analysis (MSA), Technology Development (TD), Engineering and Manufacturing Development (EMD), Production and Deployment (P&D), and Operations and Support (O&S). The documents associated with the JCIDS process are depicted in Figure 4 as pink rectangles amid the green squares marking sponsor activities and blue triangles indicating acquisition decisions. The documents include the Initial Capabilities Document (ICD), the Capability Development Documents (CDDs), and Capability Production Documents (CPDs; CJCS, 2012).
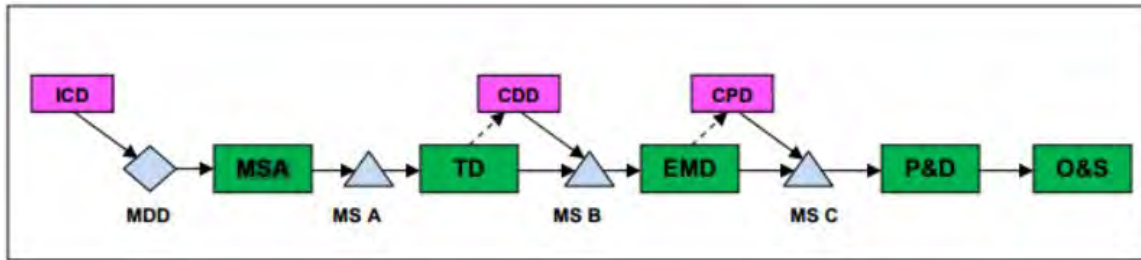
Figure 4.   JCIDS Interaction With the DAS (from CJCS, 2012, p. A-6)

3. Defense Acquisition System

The DAS, as seen in Figure 5, is a process guided by events. The materiel development decision (MDD) is the initial entry point into the DAS. There are three milestone reviews—A, B, and C—and several additional decision points within each phase. Milestone Decision A is characterized by a conclusive materiel solution analysis that indicates a direction to be taken toward effective development of a suitable solution. Milestone Decision B is characterized by completion of the development of appropriate technology as well as the conduct of a preliminary design review. Milestone Decision C occurs at the close of the EMD phase and is characterized by a program prepared to send a system into low rate initial production (LRIP) with plans for introductory operations, training, and education leading, creating an initial operational capability (IOC) for the warfighter. Subsequently, a full rate production (FRP) decision is made and the status of

full operational capability (FOC) is achieved as the system transitions into the post-acquisition sustainment phase (DAU, 2014a).
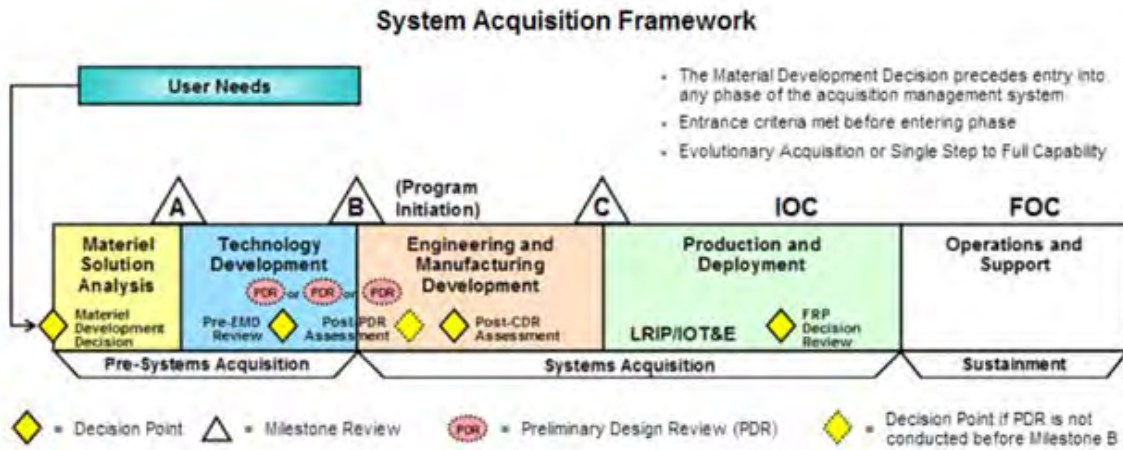
Figure 5.   The Defense Acquisition System (from DAU, 2014a)

4.   Planning, Programming, Budgeting, and Execution

Without sufficient resources to enable the process, acquisition is incomplete. The PPBE process takes its guidance from the president and his national security strategy, and funding is authorized and appropriated by Congress. Since 2003, the budget has been put together for two-year periods to effectively correspond to the president's four-year term, as detailed in Figure 6 (DAU, 2014a). In the *Quadrennial Defense Review* (QDR), the president sets the agenda for defense spending over the duration of his term. The programs budgeted for by each service correspond to the QDR priorities. The Program Objective Memorandum (POM) process provides the services an opportunity to prioritize resource requirements and compete for available resources to fund those priorities.

PPBE Two-Year Cycles Corresponding to Four-Year Presidential Terms

Year 1 (Review and Refinement):
    New National Security Strategy
    Off-year JPG as required (at discretion of SECDEF)
    Limited Changes to Baseline Program
Year 2 (Formalize the Agenda):
    Quadrennial Defense Review (QDR)
    – Aligned with PB submission in second year of an administration
    On-year SPG/JPG (implementing QDR)
    Fiscal Guidance Issued
    POM/BES Submissions
Year 3 (Execution of Guidance):
    Off-year JPG as required (at discretion of SECDEF)
    Limited Changes to Baseline Program
Year 4 (Ensuring the Legacy):
    On-year SPG/JPG (refining alignment of strategy and programs)
    Fiscal Guidance Issued
    POM/BES Submissions

Figure 6.   Planning, Programing, Budgeting, and Execution
(from DAU, 2014a)

Defense spending has been receding after a robust decade of spending in support of ongoing combat operations. As a result of spending reductions, effective prioritization is critical to each service to ensure that each is able to meet capability requirements in the most effective and efficient way possible.

In addition to the overarching Big "A" concept and processes, there are best practices that evolve to support procurement of the best possible resources. Prototyping is one of those best practices. The Weapons Systems Acquisition Reform Act (WSARA) of 2009 formalized prototypes into the acquisition cycle through a mandate for competitive prototyping.

B.   PROTOTYPING

Prototyping has become an integral element in the acquisition process, though there is not a strict framework for how it must be accomplished for individual programs. Competitive prototyping is the only version with statutory requirements for MDAPs. There are additional options beyond competitive prototyping that can support acquisition efforts through the process.

In the 2012 GAO report, the comptroller general of the United States, Gene Dodaro, pointed out that on a positive note, several MDAPs are employing strategies such as competitive prototyping in an effort to control costs. Competitive prototyping is required by the WSARA of 2009. Using prototyping to "reduce technical risk, refine requirements, validate designs and cost estimates, and evaluate manufacturing processes" (GAO, 2012, p. 30) can ideally mitigate cost increases later in the acquisition process. The *Defense Acquisition Guidebook* (DAG) highlights the benefits of prototyping by pointing out that prototypes could potentially support acquisition of "more innovative solutions at better value" (DAU, 2014a, para. 4.2.4). The DAG goes on to lay out a flexible guideline that the competitive prototype can focus either on a full system or portions thereof, such as critical technology or system elements.

1.   Competitive Prototyping

Some see early prototyping as a potential pitfall and limiting factor rather than as an enabler. A prototyping skeptic would argue that early exposure limits the aperture of possibilities and stifles creativity. From a design perspective, this argument may have merit; however, competitive prototyping aims to reveal multiple potential solutions, each a unique approach to meeting the system requirements. Competitive prototyping is a mandate in the WSARA of 2009 during the technology development phase prior to Milestone B decisions where the Milestone Decision Authority grants entry into the Engineering and Manufacturing Development phase (WSARA, 2009). Competitive prototyping invites competition from commercial vendors but does not explicitly attempt to bring in novel or leap-ahead solutions. Competitive prototyping can result in great motivation for vendors to provide innovative solutions, and can help ensure acquisition dollars are spent toward development and evaluation of a near-final production solution. However, costs can quickly escalate if requirements creep occurs during this phase. Costs associated with competitive prototyping include producing a mockup of the system or sub-systems for evaluation against competitors (WSARA, 2009). The WSARA affords a program manager the opportunity to request a waiver if the expense of a competitive prototype is not economical, given the anticipated system life-cycle cost. ESP can bring the positive features of competitive prototyping, such as requirements refinement, into

the low cost, government-directed tradespace of a virtual environment before a physical prototype is produced. The ability to refine requirements facilitates pre-Milestone A concept refinement and supports acquisition process improvement.

William Fast (2014) made a concerted effort to evaluate fairly the effectiveness, or lack thereof, of competitive prototyping. Fast looked at programs from 1990 through 2012 that "demonstrated technology maturity on prototypes in a relevant environment" (p. 469); indicated a Technology Readiness Level of 6 (TRL6); and, also accomplished a preliminary design review before Milestone B. His research revealed that programs that met these two criteria "more often to show negative PAUC cost growth" (p. 469).

Fast (2014) was also able to show that these programs were not less likely to suffer a schedule breach. The seemingly mixed results of this effort are further muddled by process change that was incorporated during the researched timeframe as well as variant criteria used in previous research. The results echo the findings obtained by Jeffrey Drezner in a 1992 RAND study. Drezner concluded that the "effect of prototyping on program cost, schedule, and performance is ambiguous due to the effect of confounding variables" (p. 68). Ultimately, in the absence of clear quantification of competitive prototyping benefits, the acquisition can look back to Drezner's recommendation that each program manager must "weigh the cost and benefits of prototyping against the risks and consequences of proceeding into the next phase without the knowledge gained from prototypes" (Fast, 2014, p. 467). It is easy to understand why many acquisition professionals continue to consider the risk mitigation achieved through seeking out and evaluating prototypes more valuable than the possible limitations of employing a prototype.

2. Other Prototyping in Acquisition

Competitive prototyping is not the only type of prototype that can be employed to support successful system development. Defense Systems Management College (DSMC) Military Fellows Garcia, Gocke, and Johnson proposed virtual prototyping as far back as 1994. Garcia et al. (1994) produced a comprehensive product that factored in the post–Cold War-reduced military funding environment along with the spectrum of technology available to support creation and evaluation of virtual prototypes within synthetic

environments to complement ongoing acquisition efforts. Binder (1998) proposed an implementation of virtual prototyping for industry in 1998 to support efforts of engineers to build a model and simulate its moving parts to optimize designs before the more costly action of building a physical prototype or proceeding directly to manufacturing. Virtual prototypes can be used to model and review systems before making a commitment to evaluate a physical prototype or, alternately, eliminate the need for the physical prototype altogether given substantial risk mitigation to offset the inherent limitations of virtual renditions of systems.

Given the structured environment employed to ensure that the nation's needs are met within available resources in a fiscally responsible manner, prototyping can be an integral part in the acquisition of new resources for the DOD. Hencke (2014) proposed that prototyping is maturing from a design tool into "a collection of developmental and experimental activities that are maximizing the value of developing and working with intermediate forms (models or demonstrators)" (p. 11). He divided prototypes into two distinct instruments: developmental and operational. Figure 7 shows functions of each instrument and alignment within acquisition and technology readiness. Hencke (2014) pointed out that there is an additional requirement for prototyping "to the left … where problem definition and concept development reside" (p. 14).
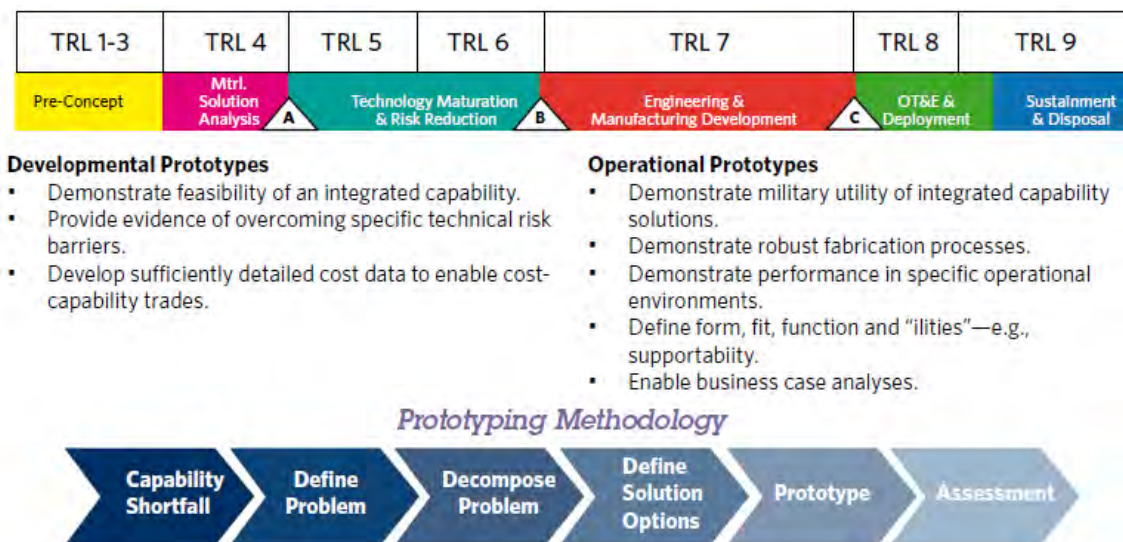
Figure 7. Prototype Instruments and Methodology (after Hencke, 2014)

Expressing support for prototypes in support of innovation, Alan Shaffer, an aid to the under secretary of defense for Acquisition, Technology, and Logistics (USD[AT&L]), argued that prototypes are essential in the early stages "before [going] to formal lockdown of requirements at Milestone B" or Critical Design Review because, after that point, it is challenging to incorporate additional S&T because a "program must focus on schedule, budget, and getting new technologies to work reliably" (Freedberg, 2014, para. 9).

C.   SIMULATION IN ACQUISITION

There have been several attempts to incorporate simulation or virtual prototypes into the acquisition process to include efforts to leverage simulation to reduce costs in system design as well as in test and evaluation.

1.   Simulation-Based Acquisition

Simulation-Based Acquisition (SBA) debuted in 1997 as a concept to incorporate powerful aspects of simulations in support of acquisition. ESP appears to be very similar to SBA; however, there are two important distinctions: (a) ESP is focused on early concept development, when costs are relatively low but when it is critical to get major design decisions right; and (b) ESP allows for the consideration of more design alternatives than SBA or any known acquisition process options by many orders of magnitude. ESP operates on the premise that disruptive ideas are more likely to appear when 10,000 design variations are considered rather than just 10.

SBA promised a reduction in time, resources, and risk associated with the acquisition process and an increase in the quality, military utility, and supportability of the systems it fielded (National Research Council, 2002; Sanders, 1997). Despite its merit as a means to reduce expenditures by introducing modeling and simulation into the acquisition cycle, SBA achieved limited success partly because it attempted to address the entire life cycle from idea inception through production, fielding, and employment. The use of simulation at each phase of the acquisition process differs. Rather than take a holistic approach to simulation in acquisition, ESP seeks to address the unique needs of the early phases. The ESP approach also serves to shift the bulk of the change demand,

particularly the demand coming from the warfighters ultimately expected to employ the system, from post–Milestone C, when it is expensive to make changes, to pre–Milestone A, when it is far cheaper.

2. Simulation and Modeling for Acquisition, Requirements, and Training

Simulation and Modeling for Acquisition, Requirements, and Training (SMART) attempted to model physical properties and associated costs in a virtual environment at an early stage and carry those through the fielding and training phases (Davis, 1999). The holistic approach of SMART offers a contrast to the focus of ESP. By limiting its focus to the early design phase, ESP has greater latitude regarding the level of precision required to explore an early concept as compared to detailed design decisions later in the acquisition process. During concept exploration, the fidelity of a ballistic model, for example, is of less concern than determining whether a weapon system used in a specific way merits further study.

3. Dragonfly

The DAU is using a product called Dragonfly as a teaching aid in the program manager course (DAU, 2010). Dragonfly simulates the tradespace with realistic portrayal of cost and performance factors. The interface to the environment, as seen in Figure 8, is easy to use, allowing a player to select preferred components and then weigh associated capability against cost. System performance is evaluated head-to-head against peers in the Dragonfly virtual environment. The diversity in selected technical solutions presents an opportunity to explore a variety of solutions in a standard trial environment (see SEA in the next section, Chapter II, Section C, Part 4, which proposed this as well). The potential for multiple optima emulates the crowdsourcing objective of ESP and provides a space to refine requirements against possible and plausible technical solutions.

Figure 8.   Dragonfly User Interface (from DAU, 2010, p. 8)

A doctoral dissertation by Major Josh Keena (2011) used MindRover, the precursor to Dragonfly. Keena used this tradespace environment to run trials with 18 vehicle variants, each of which had binary configuration options for consideration. Keena (2011) amassed data from 14 participants, running 15 different missions, on 10 randomly assigned vehicle variants totaling approximately 100 missions per vehicle. The binary configuration options he used were

- tracked versus wheeled,

- levels of survivability (two levels),

- levels of lethality (two levels),

- levels of mobility (two levels), and

- two training vehicles.

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Through this effort, Keena (2011) gained insights that support further efforts for ESP by looking at the vehicle's mobility, lethality, and survivability in concert. The environment offered useful tradespace feedback based on the binary input options as well as output metrics on mission success/failure, mission time, and vehicle health. The virtual environment offers a superior evaluation environment in that there was no degradation in operator performance from fatigue (Keena, 2011). From the warfighter perspective, the reduction of fatigue affords each alternative being considered a more consistent evaluation environment.

4.   Synthetic Environments for Assessment

Rudolf Darken and Joseph Cohn (2012) sought "nonlinear innovation" through Synthetic Environments for Assessment (SEA) to optimally support achievement of a leap-ahead solution that could disrupt the status quo and propel warfighters to a clear advantage. SEA has many of the same objectives as ESP but is focused on human systems (man-in-the-loop) specifically investigating the trade-offs between users (including teams) and equipment. SEA calls for "calibrated scenarios" that are validated and realistic to be used for testing ideas. It also identifies the need for reusable components (models and software) to ensure repeatability in assessment (Darken & Cohn, 2012). These concepts are likely to enhance ESP in the future.

5.   System Engineering 2025

System Engineering (SE) 2025, as proposed by Robert Smith and Brian Vogt (2014), could incorporate ESP at the front end of a process that aims to provide flexible and adaptable solutions for rapid fielding even at austere locations by leveraging techniques such as additive manufacturing. This approach on "mass customization" is based on enabling a platform in which soldiers and engineers can collaborate on technology solutions as well as the tactics to employ the technology. SE 2025 seeks to be an enabling technology in its own right, supporting warfighter needs in a more rapid fashion (Smith & Vogt, 2014).

## 6.	Framework for Assessing Cost and Technology

A tool currently employed by the Marine Corps is the Framework for Assessing Cost and Technology (FACT), which incorporates simulation into the life-cycle management of a system (O'Neal, 2011). There are extensions in development to bring FACT into a simulated scenario environment for rudimentary evaluation of features given specific conditions and mission demands (Ender, 2014). To facilitate the evaluation of trades between capabilities and available resources, tools are required to visualize information. FACT is a highly refined and capable design trade-off analysis environment that effectively meets these goals for evaluation and visualization (Velazquez, 2014). FACT offers an open-architecture web service to provide rapid exploration of engineering design trade-offs (Yates, 2012). Performance, reliability, risk, and cost over the life cycle of a system can be explored in this comprehensive, near-real time, government-owned resource built for the Marine Corps (O'Neal, 2011).

The detail, fidelity, and physically based accuracy presented in the FACT environment far surpasses what is envisioned for ESP. Rather, ESP is a precursor where design ideas are accumulated, vetted, and accepted or discarded based on estimates of performance. FACT is a tool to hone a good design into a better design. ESP is a tool to help find the good design in the first place. Alternately, refined solutions developed and assembled in the FACT library could be made available for emulation in ESP (in an iterative design process) to assess performance in a specific operational environment or a novel tactical employment scenario. In conjunction with FACT, ESP provides the opportunity to demonstrate virtual employment of a combat system in a combat scenario while garnering contributions from a wide breadth of experienced users.

## 7.	Executable Architecture Systems Engineering

Executable Architecture Systems Engineering (EASE) is a collaborative environment in which to assess the detailed systems concepts that are developed in FACT (see Figure 9). Beyond the feature and functionality tradespace offered by FACT, EASE provides the opportunity to examine measures of effectiveness and provide results that can be sent back to FACT for further evaluation and "tradestudy" (Ender, 2014, p. 3).

The enterprise architecture established between FACT and EASE is similar to ESP but does not contain the critical inclusion of input and participation from a variety of subject matter experts (SMEs) across the spectrum of military operations, found by using a crowdsourcing technique to solicit and vet input from a much broader variety of contributors than the science and technology contributors who would automatically be involved in critical coordination and decisions on a program of record.
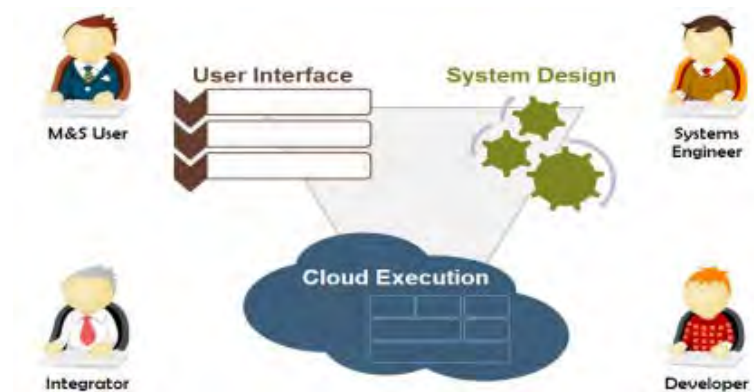
Figure 9.   EASE User-Level Interfaces (from Lesinski, McCarthy, & Gaughan, 2013)

D.   GAME ANALYTICS

Measurement within games, or game analytics, is a way to glean useful information from game play that players may or may not be aware is being collected. Games provide an inclusive way to accumulate input and feedback from participants without creating an unnecessary burden. Games can invite creativity and encourage responses from those who might not otherwise participate. Like any mode of entertainment, video games need an audience to maintain viability. The potential for profit has led game developers to take a closer look at what they are developing, how it is being developed, and what aspects garner the most loyalty, reinforcement, and profitability from their player population (Seif el Nasr, 2013).

The astronomic growth of the video game industry has motivated developers and publishers to seek an edge in determining the makings of a great game as compared to an ordinary game. Game analytics is a burgeoning field of study that addresses this need. In

a comprehensive collection of work on game analytics and its application, Seif El-Nasr, Drachen, and Canossa (2013) provide a definition of game analytics, which they describe as

> the process of discovering and communicating patterns in data, towards solving problems in business or conversely predictions for supporting enterprise decision management, driving action and/or improving performance. Game analytics is a specific application domain of analytics, describing it as applied in the context of game development and game research. (pp. 14–15)

Seif El-Nasr et al., further breaks the definition of game analytics into two distinct segments: the "game as a product" that should provide a good user experience, and the "game as a project" (p. 15) that should perform well on its own and in comparison to other games. ESP is concerned with both product and project: continuous interest from players and a well-developed game environment capable of handling the desired user load and sufficient instrumentation. In ESP, akin to the game developers, S&T experts working with a program office can advise the program manager about what data to collect and how to correlate that data effectively to inform decisions for the program.

Game developers intend to craft games that achieve commercial success. That commercial success is based on a positive user experience. The ability to observe player actions and reactions in the game environment offers the opportunity to dynamically update a game to maximize the monetization of players. Game analytics can be applied to inform decision-making by providing a myriad of information to supplement other available business intelligence data. Games are not always played on-site for developer observation; therefore, telemetry (data obtained over distance) provides a view into a player's decisions and resulting success, failure, and game behavior (Seif El-Nasr et al., 2013, p. 16). Game metrics are interpretable measures of something related to games— quantitative measures of attributes of objects within the game environment. Microsoft uses Xbox Live data from 18,000 volunteer players to capture games played, achievements earned, and inferred presence information. The data comes through an XML feed from each player's Xbox. Microsoft also mines online communities for

threads relevant to games under development (Zimmermann, Phillips, Nagappan, & Harrison, 2012).

Within the first-person shooter genre, metrics that might apply to ESP include "weapon use, trajectory, item/asset use … loss/win, heat maps, team scores … vehicle use metrics, strategic point captures/losses … avatar movement and posture, … AI-enemy damage inflicted, and projectile traces" (Seif El-Nasr et al., 2013, p. 25). None of these metrics require special instrumentation or hardware. Players are unaware that data is being collected. Gleaning useful *strategic* information is more difficult. Parameters that may apply to strategies employed may include monitoring the frequency of the previously mentioned attributes, such as event frequency and events initiated.

E.   REACHING THE CROWD

Crowdsourcing in the context of ESP is the practice of obtaining ideas by soliciting contributions from a large body of players. Gaining access to a significant volume of information without negatively impacting the body providing that information is a worthy goal. Consequently, game analytics that are transparent to the players are essential. Crowdsourcing is employed in such venues as massively multi-player online games (MMOGs) where troves of data on character/player activities can be collected, parsed, and evaluated for relevance. The Entertainment Software Association (ESA) 2013 report of sales, demographics, and usage data stated that "62% of gamers play games with others either in person or online and 77% of gamers who play with others do so at least one hour per week" (p. 5). At comparable rates, the amount of data that could be captured from several hundred warfighter players is substantial.

The ESP framework will need to be easily accessible via the internet to allow players across the country to access the game environment off duty, or even on duty if it is deemed appropriate or necessary. Keeping players coming back to the game environment to play a variety of systems in multiple scenarios offers the ability to longitudinally track their valuable inputs and progression through the game environment, which is a necessary requirement for ESP to succeed.

F.   LIMITATIONS OF GAMES

By its definition, a game is "a physical or mental activity or contest that has rules and that people do for pleasure" ("Game," 2014). This definition, at face value, would not lead one to believe that a game could be useful for practical purposes. Finding a balance between the generally accepted principle that games are for pleasure or entertainment rather than for the development of functional outcomes is critical to employment of a game environment for the purpose of conducting a practical simulation in support of acquisition. Commercial video game developers use game analytics in part to aid the creation of more entertaining games to build a strong customer base. Therefore, ESP will be competing against countless computer and console game options for the time of the warfighters. Keeping players engaged and returning to play in ESP will be a challenge.

As games become more complicated, the cost of developing and running those games will increase. Cost can be interpreted as pay for a programmer to build a more realistic, higher fidelity model, the cost of a more robust platform in which to host the more complex models and scenarios, and also the computational cost of rendering on screen and communicating between distributed players and the game server. If the game fidelity is made too complex, individuals using less capable resources, such a low-cost personal laptop, may not be able to play the scenarios at a satisfying level in a real-time online environment. Given the multitude of competitor game-play options, such as smartphone applications or console games, unsatisfied players may elect to spend their time doing things other than playing ESP scenarios. The counter for ESP is the altruistic proposition that the warfighters engaging in game play have a vested interest in the successful development of future DOD systems.

A game environment may not be able to convey robustly some challenging aspects of system development, such as logistics. Care must be taken to consider logistical realities that may be elusive in a game environment. Damage to a system, the need to conduct preventive and corrective maintenance, and the requirement to recharge or refuel assets prior to or during employment are a few examples that would be challenging to represent in a game environment. In short, logistical concerns can be modeled but might lack detail to keep players engaged in real time or produce reliable

outcomes. Much as actual final validations of system models cannot be accomplished in the virtual realm of a game, challenging concepts, such as logistics, will need follow-on evaluation in a more robust, higher fidelity environment. ESP is proposed for early stages of evaluation and development where a multitude of options can be considered.

Despite the potential limitations, the ubiquity of games is evident in that they are played by 58% of Americans, and 51% of American households have at least one game console (ESA, 2013). The pervasive presence of video games makes the game environment a promising venue in which to communicate with and collect data from the crowd of warfighters across the DOD in the early stages of concept development.

G.   DOD DECISION SUPPORT

There is a strong juxtaposition between the formal, highly organized process map of the DOD decision support framework and the malleable platform that can be developed in a game environment. The game environment offers a venue that widely engages a principle stakeholder—the end user—without the intimidation that can occur when dealing with the processes related to the JCIDS, DAS, and PPBE. Crowdsourcing allows for contact with and extraction of critical information from a wide population of users. Crowdsourcing within ESP also solicits the expertise offered by S&T professionals seeking out profound technology developments. This objective is not modest, but meeting it will help the United States maintain its technological dominance on the battlefield.

III.   EARLY SYNTHETIC PROTOTYPING CONCEPT

ESP offers an opportunity for exploring proposed systems and system characteristics in the low-cost tradespace of a virtual environment. Using a game environment as a platform is a way to reach out to a broad population of users to gain input from those with either current operational experience, technological savvy, or both. Within the game environment, the warfighters can provide input, feedback, and proposals toward systems and methods of tactical employment bringing ESP.

A.   THE CONCEPT

ESP is a process and set of tools that enables warfighters to inform technology development and acquisition decisions by assessing emerging technologies in a game environment. Collaborators in acquisition, S&T, and industry can develop models and scenarios for play and assessment. ESP allows an unbounded increase in potentially disruptive ideas to be explored at minimal cost by inviting warfighters at all levels to drive, define, and refine future systems.

The DOD needs a means to complement or reinforce the competitive prototyping effort and ensure that requirements and evaluation criteria are clear prior to soliciting for physical prototypes. Figure 10 depicts hypothetical cost and value curves based on increasing fidelity of prototype medium. The green arrow shows where ESP will seek to exploit the gap between preliminary sketches and high fidelity simulations, such as FACT and EASE, using a game environment. The relative gain in value and relative increase in cost of a game environment over pencil sketches is better than what could be achieved by skipping to a high fidelity model and simulation. Each increasing level of prototype fidelity provides some overlapping as well as distinct opportunities to develop insights. Ultimately, the closer the prototype is to the actual production system, the higher the value and level and of insight researchers and future users will have into the system, and how that system can be effectively employed.
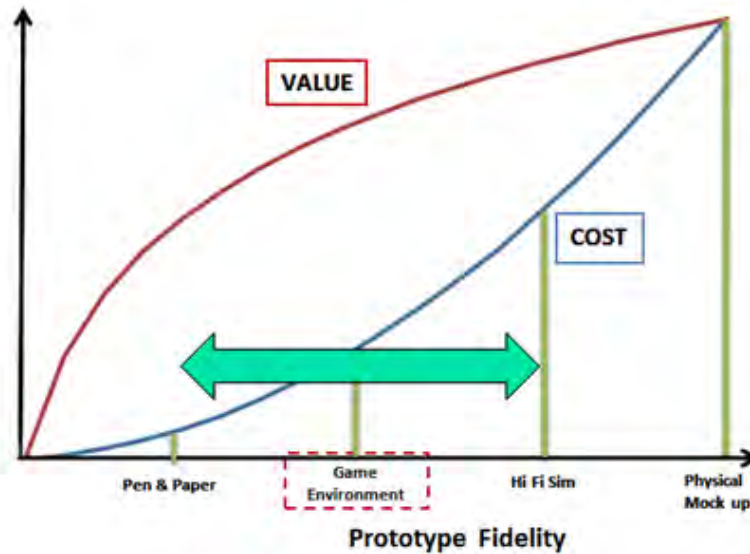
Figure 10. Hypothetical Cost and Value Curves Based on Increasing
Prototype Fidelity (from Murray, Darken, Vogt, & Goerger, 2014)

ESP can be accomplished in support of successful acquisition of modern and effective programs of record. The ESP framework will be capable of providing early, cost-effective feedback from an operationally experienced source. The ideal point at which to insert ESP is during concept development. ESP could contribute the ability to evaluate multiple system variants and scenarios in support of the requirements development phase of the acquisition cycle. Employing ESP has the potential to develop a strong foundation on which to proceed with acquisition on any scale. From this vantage, ESP can become the cornerstone of the greater effort toward Engineering Resilient Systems (ERS).

1.   **Early Synthetic Prototyping: A Cornerstone of Engineering Resilient Systems**

ESP is not a holistic solution, but rather a concept that fits into the greater acquisition cycle. More specifically, ESP will become a cornerstone of ERS, which is intended to address the *entire* acquisition process, not limited to the early concept phases. (See Appendix B for a depiction of ERS interaction with the acquisition cycle.) ERS seeks to enable better acquisition decisions by providing a rigorous science and engineering process on an open framework for requirements generation, analysis of

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alternatives, and prediction of life-cycle performance and costs (Goerger, 2014). ESP should be considered one facet of what ERS will eventually become.

The assistant secretary of defense for research and engineering (ASD[R&E]) has made ERS a priority to focus on improving engineering, design, and development of defense systems through targeted application of science and technology. Figure 11 depicts how ERS seeks to link warfighter needs across common platforms, such as reliability and sustainability, with S&T resources to collaborate toward producing a robust portfolio of rapid, reconfigurable systems. As described by Tommer Ender (2014), ERS aims to accomplish development of, among other aims,

- "more complete and robust requirements" supported by an increase in the parameters and scenarios used to help set those requirements (p. 4),

- a quantified adaptability to a changing mission (p. 4), and

- "reduction in time to complete systems by reducing rework" (p. 4).
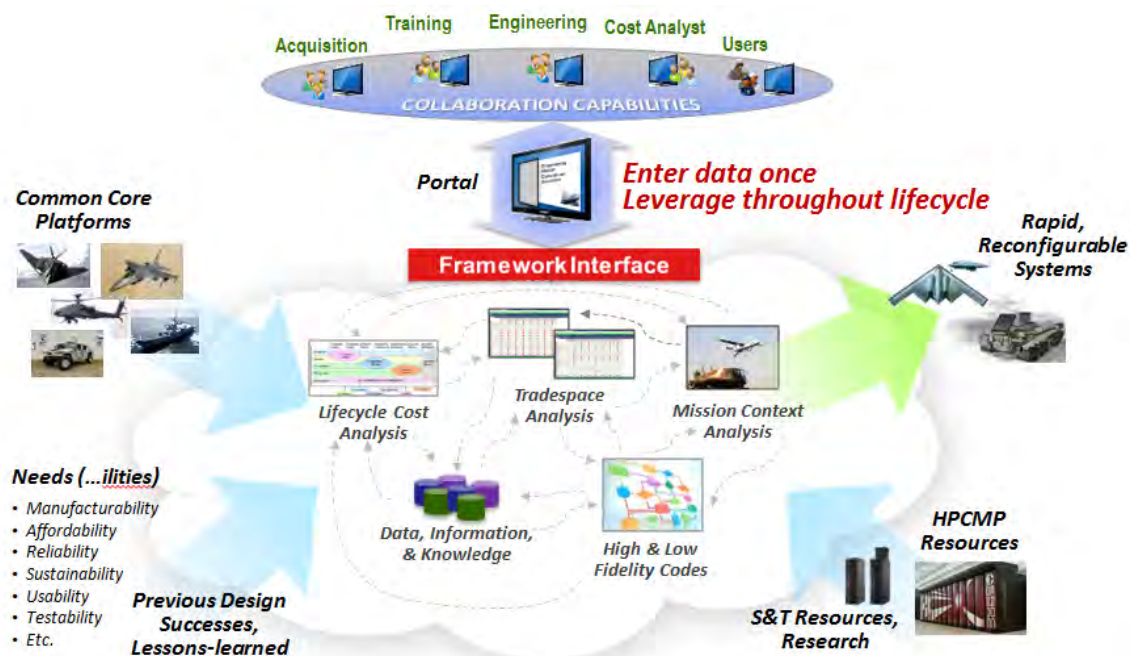
Figure 11.   Engineering Resilient Systems Concept (from Goerger, 2014)

2. Early Synthetic Prototyping: Sources for Innovation

The DOD has often looked, with limited success, outside the defense establishment for potentially disruptive change. The private sector is not well tuned to understand modern warfare and all the subtleties that differentiate a revolutionary idea from yet another evolutionary improvement. In the July 2014 edition of *Army Magazine*, Hill and Allen proposed that innovation in a military context can be accomplished through "brilliant mistakes" (p. 30) and "anomaly-seeking behavior" (p. 28). Further, they offered that "in war, a gap between expected and actual performance of a plan, tactic, or system creates a demand signal for change" (Hill & Allen, 2014, p. 28). The creativity and innovative spirit for disruptive change exists in each service member, but it remains a largely untapped resource. ESP can provide an opportunity to harness that resource, allowing for the free flow of ideas to both identify and assess capabilities and tactical employment concepts early in the design phase. At this point in the acquisition cycle, the cost of change is lower, and making changes to requirements and specifications does not have voluminous second- and third-order effects. ESP offers a low-cost, flexible tool to augment requirements development through a medium familiar to warfighters—gaming.

ESP uses a distributed game network as the medium to open a conduit for the flow of ideas. Rather than relying exclusively on expert designers within acquisition programs to generate a small number of good ideas that are then prototyped, tested, and revised (at significant cost and time), ESP facilitates the development of an unbounded number of design options in the concept phase. Those options are tested and assessed as virtual prototypes in a game network. Warfighter players "play" the virtual systems while analysts gather data via game analytics to identify what works and what does not.

ESP proposes the use of a crowdsourcing technique to assess the utility and efficiency of virtual prototypes. Crowdsourcing works only if the number of players is very large. With a large crowd of collaborators, no single player is assumed to be an expert in design or assessment. Rather, as a group, the crowd is capable of contributing to the design process (Surowiecki, 2005). ESP players could be anyone from a private fresh out of boot camp to an experienced combat veteran. The assumption stands that all

contributors have something interesting to offer. Therefore, ESP does not concern itself with weeding out bad designs; players do that. The purpose of ESP is not to find the perfect design; it is to find the best possible subset of virtual prototypes for acquisition professionals, such as program managers, to pursue further hand in hand with their science and technology partners. The pursuit can be conducted with confidence that one of the ideas is, at best, a game changer, and, at worst, a practical solution, based on evidence displayed through ESP. Additionally, ESP offers the opportunity to explore force design and force employment in conjunction with capability development at the operator and small-unit levels. The ability to observe tactical employment of a system without going to the expense of engaging troops and resources in a physical exercise offers the opportunity to explore far more options and then to highlight which options deserve further review.

B.   THE BENEFIT

ESP is a persistent game network with instrumented scenarios and metrics for exploring alternative future designs to inform present decision-making. The stakeholders include warfighters and acquisition professionals in government and industry, and science and technology programs. Figure 12 identifies the principle benefit of the incorporation of ESP, moving the change demand from its current position late in the acquisition cycle to a much earlier position where the cost of change is more reasonable and can be readily adapted into the program's budget and schedule. With a reduction in costly late-stage changes, customers throughout the DOD will be able to employ the right systems in a much more efficient manner, reducing the need to unnecessarily refit systems after production.
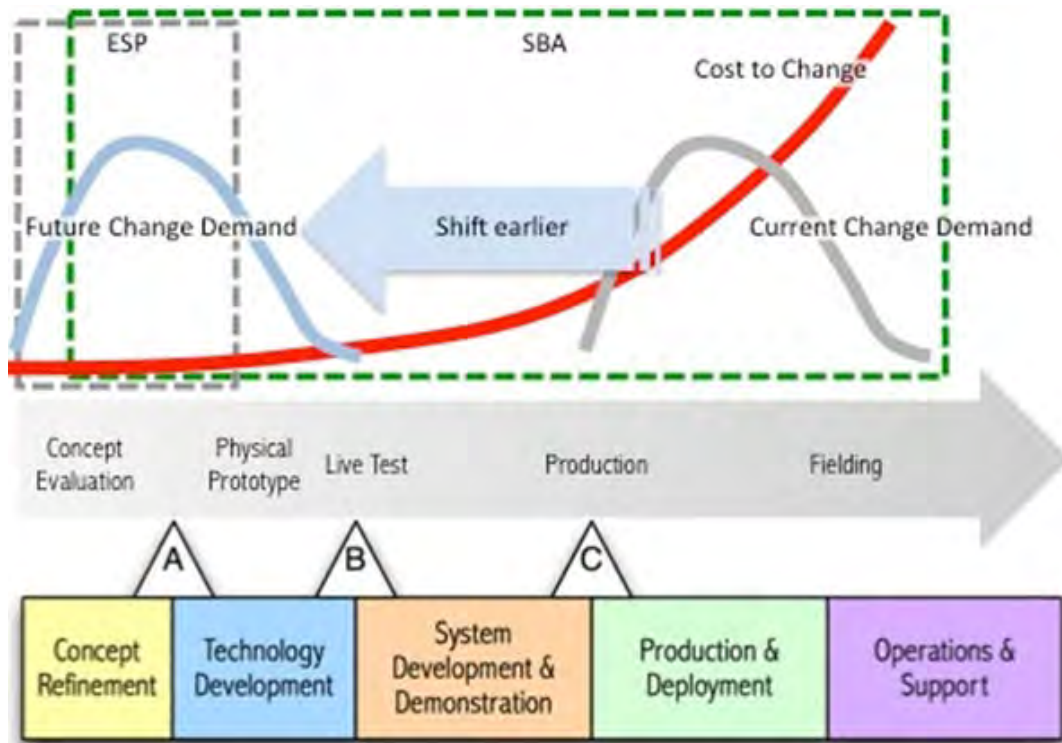
Figure 12.   Shift of Change Demand With ESP (from Murray et al., 2014)

ESP builds on ideas and concepts outside of the military. For example, Wang et al. (2008) entertained the notion that a synthetic environment could be used in industrial product design as a tool to communicate concepts for "traditional prototype evaluation, or collaborative, interactive, user-centered dynamic prototyping" (p. 3). Beyond prototype development and evaluation, Wang et al. (2008) proposed scenario-based design (SBD) to allow participants to adapt a scenario to further communication of the individual's perspective of the concept under development. ESP builds on these ideas and brings it into the DOD acquisition framework.

Referring to the ESP schematic in Figure 13 (see Appendix C for a larger image), acquisition professionals (1) use scenario editing tools to develop concept ideas for testing. These are playable scenarios (2) that are instrumented with metrics of interest (e.g., system selected, rounds fired, speed attained, distance traveled) specified by the program office. These scenarios are made available for play via a game server (3) that allows distributed warfighter players (4) to play, capturing diagnostic information.

Communities of players are coordinated via conventional social media (5). Players can modify scenarios locally. ESP does not assume the best scenarios will come from the program office. More likely, the best ideas will be modifications of those ideas made by players. Game-play diagnostic data (6) and modified scenarios (7) are returned to the server and then to the program office (8). Program offices can also interact with players via the community (9). Science and technology programs (10) will use ESP to test new ideas at minimal expense before follow-on larger investment. They will also use ESP to demonstrate concepts to potential transition customers (11) to obtain buy-in early, which will facilitate an increase in successful transition to programs of record.

Figure 13.   ESP Schematic (from Murray et al., 2014)

C.   THE BARRIERS

The ESP concept has great face validity as a way to explore new ideas. But presently, it is only a concept. A number of critical steps must be taken before it is realized, specifically as outlined in Table 1.

Table 1.   Critical Steps for Early Synthetic Prototyping

The network must be distributed worldwide and playable by any authorized player.	The game *America's Army* accomplished this over 10 years ago (Zyda, Mayberry, Wardynski, Shilling, & Davis, 2003). This is a solved problem, but managing specialized player groups will be a challenge.
Scenario editing must be simple yet expressive.	Scenario editing for a program office is similar to level editing in game design. A key issue is setting data collection triggers to capture relevant play data.
Game play must be easy and entertaining or players will simply spend their time doing something else.	*America's Army* dealt with this as well. Just because a game is free does not mean players will play. Rather than competing for players' money, ESP will compete for their time. Players should also know that the Army is listening to what they have to say.
Players must be able to easily modify scenarios to create new designs and configurations.	Although simpler than a full-level editor, players must be able to easily modify content similar in complexity to the sand table development environment on the site Garry's Mod (http://www.garrysmod.com).
Gleaning useful information from game play must be simple, or better yet, transparent to players.	There are two inherent questions here: (1) can information be collected from game play? and (2) is it useful to decision-makers?

Chapter IV details the study we conducted at the Naval Postgraduate School (NPS) focusing on the last element in Table 1: Can information be collected from game play, and is it useful? Along with my fellow researchers, I sought to determine whether it was possible to glean useful information from game play and whether the information collected was useful to those groups responsible for the development of technology solutions and systems.

D.   OPTIONS FOR CONSIDERATION

In addition to the distributed game network allowing warfighters to play during their off-duty time, it is worthwhile to consider that there may be situations and opportunities where evaluation within a game in a locally controlled environment may be useful. Despite the proposed robust support for a distributed game environment, the ESP framework could support operations in a more controlled environment, such as a training

or simulation center. For this, a hierarchical concept is proposed where early assessments are considered by the largest possible crowd (see Figure 14). The community invited to partake is then progressively reduced to include more subject matter or design experts while particular areas are being evaluated. For example, SMEs may have a unique perspective on the intricacies required for a control interface for a system. SMEs may also need to address properties of the virtual models that require more rigorous evaluation from a physics perspective. The collection of player data and feedback could be combined with in-person feedback provided via after-action sessions, much like the post-play interviews conducted in our study at NPS. For an established program of record, the opportunity to get first-hand feedback from players immersed in the proposed technology can only complement the data points that can be collected and analyzed in each scenario.
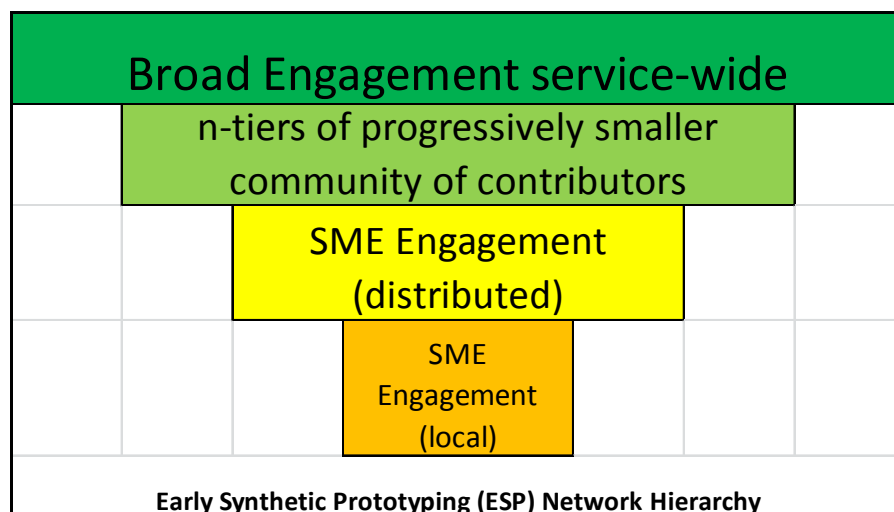
Figure 14.   Proposed Network Hierarchy

E.   MINIMUM REQUIREMENTS: A WORK IN PROGRESS

The Army has begun to develop a detailed specification for the ESP framework. The following requirements have been discussed and roughly prioritized to date and are subject to modification and update as the efforts for ESP continue into a pilot and full study in FY2015 (B. Vogt, personal communication, June 13, 2014).

- Availability to warfighters on or off duty hosted on a server accessible via web browser.

- Automated data collection of game play for automated and manual analysis. Do not annoy the player with burdensome data collection techniques such as surveys or questionnaires.

- Technical maturity of both the game environment and the visual content to ensure a quality user experience from connectivity, log-in, and game play, to vibrancy of models and terrain. Note that entertainment value need not outweigh the observation of reasonable outcomes of in-game interactions.

- Commonality and compatibility with the larger modeling and simulation community to included achieving distributed interactive simulation (DIS) compliance.

- Ability to model future (unknown) capabilities.

- Balance of government ownership with vendor proprietary material. Ideally, an innovative vendor will allow government access to make modifications when necessary and/or prioritize efforts without exorbitant fees.

- Incorporation of existing government-owned models, such as those used in Virtual Battlespace Simulation Version 2 or 3 (VBS2 and VBS3).

- Connection to a readily available and monitored discussion forum. This allows players to engage with each other, and developers to respond to requests for change or updates to prototypes and scenarios to keep them relevant and offer branches for evaluation.

- Audio connectivity to allow for real-time interaction between distributed players.

- The fidelity of physics must mimic reality but does not need to be so robust that it inhibits system performance.

- Distribution of players in small groups of four to six players initially with eventual opportunity to scale upward for larger engagement scenarios.

- User interface for ESP should initially support standard input output devices, such as keyboard and mouse with acceptable visibility on the monitor of a desktop or screen of a laptop. Incorporation of functionality for gamepads is preferred to retain buy-in from players familiar with gaming. Future development for tablet or smartphone may be considered if the system under evaluation could be supported in those environments.

F.   THE WAY AHEAD

As the Army continues development of ESP, the minimum requirements will be refined to meet the needs of this avant-guard program. With a goal for limited access and distribution in early calendar year 2015, ESP must take care not to discourage early adopters with an incomplete solution. The study conducted in support of this research effort supports the establishment of a robust ESP framework. The study sought to determine whether the game environment proposed for ESP could meet the needs of the DOD as it seeks out revolutionary technology solutions to meet warfighter needs.

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IV. STUDY METHOD, RESULTS, AND ANALYSIS

We conducted a study at the Naval Postgraduate School (NPS) at the Modeling, Virtual Environments, and Simulations Institute (MOVES). In the study, we simulated an ESP-like environment where a concept robotic vehicle was placed in a series of realistic combat scenarios and players were asked to use the vehicle to meet scenario objectives. Of particular interest were how the players would use the vehicle, what form their feedback might take, and whether their feedback would be useful to a program office responsible for making critical decisions on design and employment.

Our ESP study addressed what kind of information can be obtained from warfighters playing games to assess a novel technology solution in a virtual environment and ultimately, whether that information will be useful to the development of future capabilities. The study attempted to validate the employment of games as a tool for assessment of a proposed system, as well as rudimentary development and analysis of alternatives. The Army Capabilities Integration Center (ARCIC) in conjunction with the Army Tank and Automotive Research, Development, and Engineering Center (TARDEC) provided a novel technology for evaluation in a game environment in the form of the robotic Wingman. System models were developed in the military first-person tactical simulation environment of Virtual Battlespace (VBS2) to examine several variants of Wingman in the context of three distinct employment scenarios within the game environment. The specific questions addressed in the study were

- Can information be collected from warfighters playing with novel technology concepts in a game environment?

- Is that information useful to the development of the system or its tactical employment?

A. METHOD

The Army is exploring a semi-autonomous robotic vehicle concept called Wingman. There are many ideas for how Wingman might be used and what configurations may be made available. The robotics program at Fort Hood was a valuable resource for the development of proposed systems and employment scenarios ("Robotics

at Fort Hood," n.d.). The question arises: how should the Army examine these ideas in order to make critical decisions about how or if the concept will be developed?

Three candidate scenarios were selected for Wingman: chase (or reconnaissance), attack, and defend. For each, we developed a scenario in VBS2 as an exemplar of the problem set unique to each situation (see Table 2). In this study, player participants were not able to modify the scenarios or vehicle configurations. We did, however, ask several questions about both of those issues in the debrief interviews.

The general script that we followed in conducting the study can be seen in Appendix D, and the layout of the lab area where the game sessions were conducted is in Appendix E. The pre-game demographic survey and post-play feedback surveys can be seen in Appendices F and G, respectively. Appendices H through M contain summary transcriptions of the audio recordings made during the pilot and five game sessions.

Table 2. Wingman Virtual Battlespace Simulation Version 2 Scenarios and Descriptions

Scenario	Player Breakout	Geo-Location	Additional info
Chase	Four BLUFOR	Takistan	Night
Narrative:	A HIGH-RANKING OPFOR OFFICER is in the area of Takistan, exact whereabouts unknown. A convoy in village of Hazar Bagh will meet him. Using APDs, follow the convoy without being seen. When contact with the target is made, eliminate him, all units supporting him, and the convoy.		
Attack	two BLUFOR, two OPFOR	Geotypical Eastern Europe	OPFOR AI
Narrative:	BLUFOR in the vicinity of a heavily guarded enemy compound used as a prison for friendly forces/individual.		
Defend	two BLUFOR, two OPFOR	Porto	BLUEFOR and OPFOR AI
Narrative:	BLUFOR defending a position in the vicinity of Porto against a large but unknown number of enemy fighters.		

The study consisted of a pilot followed by five groups of four participants each approved by IRB protocol NPS.2014.0026-CR01-EP7-A. The 24 volunteer participants, in the pilot and subsequent sessions, were experienced military officers at NPS, but not all were experienced in a ground combat discipline. (See Table 3 for player demographic data.) Computer game-play frequency ranged from none (eight respondents) to over five

hours per week (four respondents). Each session took two to three hours to complete. During game play, players were co-located where they could talk to each other directly. For the attack and defend scenarios, we moved the opposing enemy forces (OPFOR) team to another room so that they could not hear the other team during planning or scenario execution.

Table 3.   Demographic Data and Game Experience of Volunteer Participants

Player Demographics				
Sex	**Male**	**Female**		
	23	1		
Service	**USA**	**USN**	**USMC**	**Canadian Army**
	3	7	13	1
Rank	**O-1**	**O-2**	**O-3**	**O-4**	**O-5**
	1	2	14	7	1
Years of Service	**1-5**	**6-10**	**11-15**	**16+**
	2	11	9	2
Specialty				
	19 different service specialties			
Game Experience	**None**	**<1 Hr/wk**	**1-2 Hr/wk**	**5+ Hr/wk**
	8	9	3	4

We refer to Wingman as an autonomous platform demonstrator, or APD. The key parameters available to configure each APD are lethality (weapons), vulnerability (armor), and agility (engine and weight). Figure 15 depicts the APDs and the environment for the familiarization scenario in VBS2. We pre-configured three versions of the APD for this study, each with a different balance of lethality, vulnerability, and agility (see Table 4).

Figure 15.　　Autonomous Platform Demonstrators Employed in VBS2

Table 4.　　Autonomous Platform Demonstrator Configurations

Name	Armor Level	Weapon	Engine Power Level
APD 25mm/7.62	Moderate	M240	Moderate
APD M134	Moderate	M134 Minigun	Moderate
APD Speedy	Low	M240	High

We used the standard desktop PC configuration of VBS2 with mouse and keyboard inputs. Each group was first read general instructions pertaining to the study and information about the Wingman concept vehicle. Each player was provided a "cheat" card keyboard function map for VBS2 with important keys highlighted. We provided a familiarization scenario that brought all players to a minimum level of competence at using VBS2 both in APD mode and dismounted mode, which are always operated separately (players either operate their APD or move their soldier, but not both simultaneously). Prior to each scenario, we gave specific instructions as to objectives of that scenario and answered player questions. We provided no coaching during scenarios, but we did answer questions related to the VBS2 interface. We gave teams five minutes before each scenario to develop a plan. We showed all players on each team the tactical map of the area in VBS2, as well as the initial positions of each player and his or her equipment on that map. We informed groups that they could play any scenario as many times as they collectively wished.

During game play, we recorded all verbal communication for later analysis. We also used the after-action review (AAR) capabilities in VBS2. The AAR from VBS2 stores the game session in real-time and can be replayed in a two dimensional (2D) map view, a three dimensional (3D) model view, or any combination of those options. For this study, there were a few automatic collection data points, such as rounds fired and the status of both enemy and friendly killed and wounded. At the conclusion of play, we brought all the participants together for a moderated debrief session. Questions centered on two main topics—those specific to the Wingman concept and those specific to ESP.

B.   RESULTS

1.   Chase Scenario

The chase scenario was preceded by a familiarization scenario. The narrative and scenario objectives were provided followed by game play and a group after-action group interview session to collect player feedback.

a.   *Narrative and Objectives*

Recent Intel suggests that A HIGH-RANKING OPFOR OFFICER is currently in the area of Takistan, although his exact whereabouts are unknown. A convoy in the small village of Hazar Bagh is set to meet him. Using your APDs, follow the convoy without being seen. When contact with the target is made, eliminate him, all units supporting him, and the convoy. Remain under cover and avoid detection. Eliminate OPFOR once contact with THE TARGET is made. No APDs can be destroyed.

b.   *Scenario Analysis*

This scenario was challenging in that it had two distinct phases that had different requirements for the APD. During the chase phase, players wanted a faster APD even if they had to give up armor or lethality. But when they reached the end of the scenario and had to successfully eliminate the target and his supporting units, players needed an APD with armor and lethality. The APD characteristics players sought for different missions suggested that players might not want APDs with identical configurations.

Because stealth is a mandatory element of this scenario, players had to master the night vision and lighting features in VBS2. The chase scenario was also the first scenario

after the familiarization that every group executed. Consequently, there was more of a learning curve here than in the following two scenarios.

A successful approach to this scenario utilized bounding overwatch with one APD to the north of the road, one to the south, and another trailing the convoy far enough back to not be detected but close enough to be able to support. As shown in Figure 16a, the convoy (5) travelled along the road between villages. It stopped at point 5b, which is where the target appears. This group had APD4 to the north of the road and APD3 to the south. APD4 kept to the high ground in order to observe all movement. APD3 also tried to remain in visual contact but was less successful. APD1 trailed the convoy all the way to the end, and APD2 remained behind as rear guard. When the target appeared at 5b, players were alerted that they should now attack the convoy. The target and supporting units moved to 5c where they were engaged by all four APDs. The players de-conflicted their fires verbally and through direct observation. This group had positioned its APDs to bind the target on three sides. During the ensuing firefight, APD1 was mostly offensive while APD3 and APD4 prevented the convoy from any chance of egress from the area. APD2 moved into the engagement area from its rear guard position and was able to support APD1. Figure 16b shows the situation immediately prior to the firefight at the end of this run.

Although successful, this group jacked into its designated APDs immediately at the start of the scenario while the virtual soldiers remained in the starting locations. This group maintained the perspective of robot controller throughout game play and never returned to the Soldier perspective. The human operators (their avatars) were not directly employed. Did they need to be on-site? One of the player groups provided feedback, suggesting that a local controller was essential, and three explicitly sought an off-site controller. The other two groups did not offer a direct opinion on the local vs. off-site discussion. Had an APD been disabled in the firefight, an on-site Soldier could move into position to physically support achievement of the objective. An off-site Soldier could not physically assist but may have had a wider vantage point for battlefield situational awareness to provide support from afar.
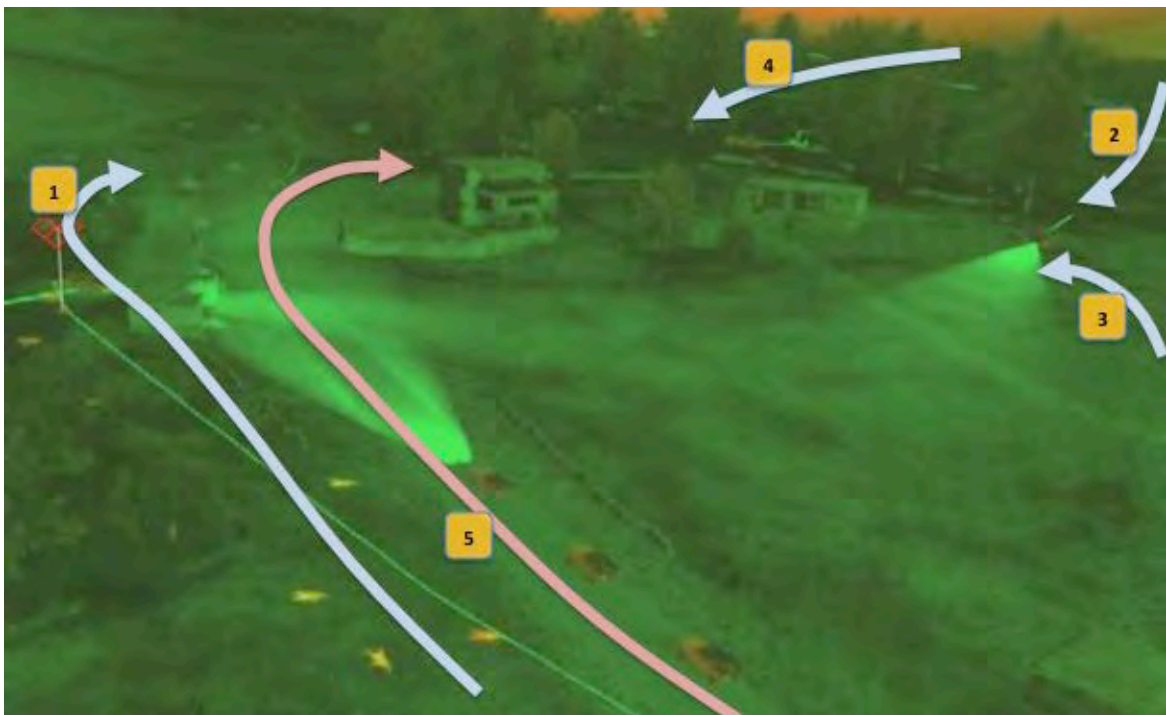
Figure 16.   Map (a) and After-Action Review (b) View of a Successful Chase
Scenario

A problem that we saw in 75% of group runs was a failure to remain undetected.
This typically occurred when an APD would follow too closely because a player would

underestimate the noise signature or acceleration rate of the APD. At the other extreme, after a delay to allow for preparation, the OPFOR convoy moved out. If Blue (friendly) force (BLUFOR) APDs lagged too far behind, they lost contact with the enemy convoy, which ended the scenario.

Every attempt at this scenario was characterized by some level of disorientation at the onset of the run. Ten players reported spatial disorientation in free-form survey comments, and all players verbally expressed challenges during play. Even after viewing a map and knowing the location of both the Soldier and APD, the discontinuous switch from a geocentric view of the tactical map to the egocentric view in the APD was difficult to overcome. Allowing the players multiple attempts at this scenario helped. By the second or third attempt, most players reduced their disorientation and executed their plan. In all, only two of 24 players were unable to effectively navigate in the game environment to meet the objectives designated in their group plan for the third attempt.

The visual display itself contributed to the disorientation. The direction of movement (shown in an inset view by default) and the direction of the turret and optics (shown in the main view by default) are controlled separately. The variant view perspectives created confusion for players. Players would think they were lined up to move forward on the road, but when they pressed the key to move, they would see that the turret was not aligned with their wheels. Overcoming the disparity in view perspective took practice and was the subject of several recommendations made during debrief (see Chapter IV, Section C).

2. Attack Scenario

Both BLUFOR and OPFOR were provided objectives for the Attack Scenario.

a. *Narrative and Objectives*

BLUFOR: The prisoners will start running to freedom once the shooting begins, but the OPFOR will shoot at them as they run away. Rescue as many prisoners as possible. Eliminate all of the OPFORs.

OPFOR: Two BLUFOR operatives with APDs are attacking. You must stop them from freeing the prisoners, but do not shoot the prisoners, even if they have escaped. Eliminate both of the BLUFORs.

b.   Scenario Analysis

This scenario presented the first opportunity for players to fight against each other. We immediately saw that having live OPFOR improved the level of player engagement on both sides. Because the ESP concept requires players to be highly motivated to play, this was an important observation.

There was a much broader set of strategies used to attempt to defeat the OPFOR. The BLUFOR is badly outnumbered 15 to one in this scenario, so a direct assault had little chance of success. To augment the two live OPFOR players, 13 additional artificial intelligence (AI) agents were included in the scenario. The AI OPFOR were armed with shoulder-fired rocket propelled grenades (RPG) capable of disabling an APD with a single shot. Two common strategies involved either stand-off and sniping and/or a flanking maneuver to get behind the compound.

In Figure 17a and 17b, we show one group's attempt to flank the OPFOR. APD1 moved a short distance to high ground with cover and, after a delay to allow APD2 to get into position, engaged targets from a distance. APD2 took a circuitous route around APD1 to the north ending on high ground behind the compound. APD1 then proceeded south along the back fence, remaining concealed whenever possible. APD2 purposely held fire until the last possible moment. The two OPFOR players had no idea where the APD1 was navigating until the APD appeared behind them.

Once shots are fired, the prisoners in the compound attempt to flee. If enough guards have been eliminated, BLUFOR achieves their mission objective. If not, the guards will shoot the prisoners rather than allow them to escape. In this instance, APD1 and APD2 had cleared enough guards to allow the prisoners to flee. The prisoners exit the compound to the east heading down the road that runs just south of APD1's position.
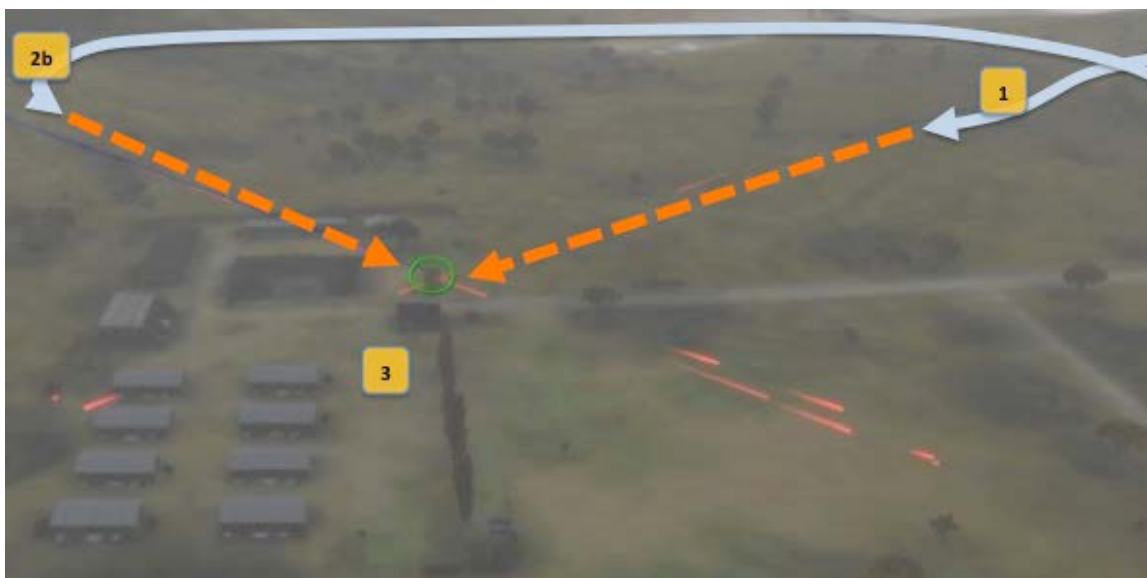
Figure 17.   Map (a) and After-Action Review (b) View of a Successful Attack Scenario

The attack scenario was less disorienting than the chase, probably due to daylight conditions. We observed far less wasted time at the beginning of each run in contrast to

the erratic movement patterns and volatile changing of view perspectives previously observed. Groups had a plan, and they executed it. The OPFOR players were also readily able to develop and execute a plan. One OPFOR group left defense of the compound to the AI OPFOR and went out to hunt the APDs and their operators. This strategy was not very successful because once the players fired on an APD from outside the compound, they were detected. The BLUFOR quickly eliminated their opponents with APDs by quickly employing effective long range sites and superior weaponry. Map usage when moving the avatar or APD was particularly important in this scenario.

Another difference in this scenario was that each BLUFOR player was given a truck to quickly move his or her Soldier to a new location if desired. Unlike the Chase scenario where it was unlikely that BLUFOR would lose an APD until the firefight at the very end, in Attack, a BLUFOR player could lose his or her APD at any time. Therefore, the positioning of the Soldier became more important to ensure cover and concealment while maintaining situational awareness of the battlefield. Even if the APD was lost, the player still had an armed Soldier to complete the mission.

The APD offered a large visible target for the OPFOR's rocket-propelled grenades. As such, more than half of the players suggested that the APD might be an excellent diversion to cover the actual movement of forces. If a group of APDs was inexpensive and essentially disposable, it might be capable of masking the movement of a large force. Another suggestion was to protect the APD with armor but not arm it with a weapon at all. Instead, it could be used as a mobile shield and supply transport for foot mobile soldiers during movement to contact.

3. Defend Scenario

The Defend scenario was the last scenario and the least preferred, as informally assessed during post-play comments and feedback.

a. *Narrative and Objectives*

Defend your position from OPFOR units for five minutes. Each of you have an APD under your control. If the APD is destroyed, you will lose 5 points and the APD will

automatically re-spawn in its original positions. If either player dies, you will lose 10 points and the enemies will all be reset to their original positions. Rescue as many prisoners as possible.

b.   *Scenario Analysis*

In the Defend scenario, APDs were used to protect an unfortified position from an attack of a numerically superior force. BLUFOR typically positioned its APDs in front of the position with avatars protected behind a solid wall. In this scenario, multiple APDs were made available so that when one was lost, a replacement was immediately available for use.

This scenario offered the least variation in strategy due to the parameters of the scenario design. The large OPFOR with RPGs, along with the availability of multiple APDs, often resulted in an APD "graveyard" in front of the unfortified position. In all sessions, the default strategy was to rely on the superior armor and firepower of the APDs to both attack the oncoming OPFOR and defend the position. Movement away from the position would have left it far too vulnerable given the number of OPFOR and the speed with which they attacked the position.

Players were least likely to request to play this scenario again. Based on its position as the final scenario, player fatigue may have played a role in the aversion to continuing with the defend scenario. An additional feature that turned players off from this scenario was a re-spawn feature factored into the game. When the OPFOR players were re-spawned, they did not always go back to their original character, leading to disorientation and confusion on how to best execute or continue execution of the scenario. The BLUFOR players and their APDs were re-spawned as well. Despite returning to the same player within close proximity to their previous location, the re-spawn resulted in considerable disorientation and dissatisfaction from players.

C.   DISCUSSION

The recommendations received from player teams were focused on (a) the Wingman concept and (b) ESP and the utility of game environments to explore new

concepts. The program office defined the critical output as the concept of operations (CONOPs) of how Soldiers most effectively used the APD and the characteristics of Wingman that allowed them to be successful. Of secondary importance was the ability to vary vehicle and scenario parameters to observe and measure the value of different performance metrics.

1. Wingman Concept

Although our scenarios in this study focused on only three pre-conceived methods of employment for Wingman, our players expanded that list significantly during the debriefing:

- *Reconnaissance*: APD has a greater ability to be aggressively applied without fear of casualty or capture. It could be configured with multiple sensors, video communications, or armament. Ground-based reconnaissance may also be a powerful alternative to UAV reconnaissance when weather interferes with the mission.

- *Transport*: Over short distances, APD is useful for transporting people, equipment, ammunition, and supplies.

- *Ambush*: APD is maneuvered to a strategic position and could lie in wait indefinitely.

- *Breaching*: APD could be configured specifically for breaching walls, fortified doorways, or other strong points that are typically dangerous for personnel to breach.

- *Mobile Mine*: If light and inexpensive, APD could be armed with explosives, quietly maneuvered into the adversary's position, and detonated.

- *Defense*: As an unmanned patrol, APDs could be used to secure or expand the perimeter. Players pointed out that, unlike with a manned perimeter, one would want the APD to take fire because this identifies the position and possible strength of the adversary.

- *Attack*: APD must be reconfigurable, possibly even within a mission (e.g., switch from one weapon to another).

ESP appears to be an excellent way to explore human interfaces with systems. As configured in this study, Wingman has limitations, but we were encouraged that the game environment was so effective at identifying what Soldiers would want the interface to be able to do. Among the recommendations were

- *Navigation*: Simplify the controller by allowing waypoints to be used so that the APD could auto-drive along a preset path to an objective bypassing obstacles through the use of sensors. The APD could have an autonomous mode that would allow the operator and APD to function simultaneously. A map chip would be useful.

- *Controller*: Wingman needs a specialized controller. The complexity of the mission did not map well to a conventional keyboard and mouse. Most players felt that a typical game controller would be more appropriate.

- *"Pre-sets":* Wingman is a complex vehicle. There are (or could be) multiple configurations for sensors, navigation, or weapons. Players wanted to be able to pre-set several configurations and then switch to each with a single button rather than work through menus to turn lights off, activate night vision goggles (NVG), and so forth.

There was a lively discussion about whether the Wingman APD should be a ground-based unmanned vehicle where the operator remains at a safe distance from danger using a sophisticated interface to control the vehicle as opposed to being controlled by an on-site Soldier who could directly see the APD. A related issue was the complexity of managing the turret and the navigation concurrently. Some players suggested that maybe Wingman should have two operators—one for the turret/weapon and one for the navigation. Players voiced concern about how Wingman alerts the operator of its damage status while employed and then how and at what level maintenance could be accomplished. As the APD takes fire, the interface does not present system "health" status to the player (e.g., status of mobility, sensors, communications, fuel/battery, ammo, and weapons). Lastly, players commented on the potential of creating a moral hazard concerning the use of a lethal robotic weapon system against a human adversary.

2. Early Synthetic Prototyping Concept

Players almost universally endorsed the concept of using game environments as a testing ground for early ideas, with 23 of 24 reporting that they would play this or similar games in the future. However, there were artificialities in our study that ESP will need to address, such as the colocation of players. They spoke freely to each other before, during, and after each scenario. ESP could use voice over internet protocol (VOIP) communications to enable speaking, but capture for analysis would be limited to processing of automated transcriptions without the ability to observe and capture inflection. Also, we gathered our players for a detailed AAR debriefing session. ESP is distributed; therefore, if there is an AAR mode, it must be meaningful to players or they will simply skip it. Our VBS2 implementation was instrumented only as far as the built-in AAR was instrumented, limited to shots fired and virtual enemy killed in action (KIA) or wounded in action (WIA). It is imperative that ESP allow the scenario author to specify metrics to be captured.

We asked players whether they would have preferred to configure their APDs from components rather than be given a specific APD for each scenario. Most said they would have preferred to build their own, especially if they had attempted scenarios multiple times. After one run, a player starts to understand the limitations of a configuration and is able to express what additional characteristics are desirable. Play also provided insights into additional information that the players would like to have known about the status of their APDs. For example, after riding over rough terrain, a player was interested in the level of damage the vehicle had sustained from the rocks and foliage the vehicle had crossed on its path. Another proposal was to incorporate waypoint movement for the vehicle to reduce the tactical navigation burden on the operator by incorporating use of GPS coordinates to lay down an efficient travel route.

The ESP concept encourages players to explore new equipment and scenarios. Again, we were encouraged by player responses, which ranged from recommendations to improve the resilience of the armor to the proposed employment scenario as a resource in support of village stability operations. We asked players whether they would author new scenarios or modify existing scenarios, provided they were given the tools to do so. There

was a mixed response to this. Some players naturally want to design new "levels," others just want to play and master the levels provided. We were encouraged to hear that a large group of players viewed scenario editing as a part of the game, or as a reason why they would want to play ESP games; it is a part of the competition.

We asked about the fidelity of the game environment. Players commented on artifacts of VBS2 that were somewhat irritating. For example, an APD became stuck on a small bush because VBS2 represented it as a solid obstacle when the real APD would have easily rolled over it. Some aspects of the lack of fidelity point to needed improvements to retain player buy-in. For example, in the attack scenario, one player attempted to achieve cover and concealment within a building in the scenario; the fidelity of the VBS2 environment we used did not accommodate this tactically sound decision. Players being stymied by the lack of fidelity occurred again in the defend scenario when players placed their avatars on the roof of a building to gain a better vantage point from which to observe enemy movement. When the player attempted to take cover, he was unable to control his APD. Finally, there were consistent negative remarks about trying to control a combat system using a desktop computer and keyboard commands rather than a game controller or joystick. Despite these readily apparent examples of the limitations of fidelity in the study, players readily adapted to these limitations and appeared to be reasonable in their expectations and in drawing conclusions about the system being considered based on what they saw in the scenarios. See Table 5 for results from several selected survey questions. The survey requested responses on the interval of 1 to 5; 1 indicating yes with certainty, and 5 indicated no with certainty. Questions with response rates recorded as a percentage were based on respondents providing a strictly yes or no response.

Table 5.　　Response Data from Selected Survey Questions.

Survey Questions (selected)		Avg response (scale 1-5)
1	Do you feel that your time was spent effectively today?	1.35
2	Would you contribute to future efforts to develop or test ideas in a game environment?	1.7
3	Would you encourage others to participate in future efforts to develop or test ideas in a game environment?	1.5
4	Would you play this game or one very similar to it again?	95%
	How often would you play if you had access ...	
4a	... via download to personal device?	65%
4b	... via internet?	65%
4c	... at work as well as designated time to play? *	80%

* 75% of respondents in this category would play more than once a week

3.　　Study Conclusions

Our ESP study produced valuable contributions to an actual acquisition program. Proposed tactics, techniques, and procedures for system employment were included in these contributions, demonstrating that ESP can excel in the areas of concern to the program office, evaluation of CONOP, and helping to build context for the proposed mission of the equipment. ESP provides a means to link capabilities to outcomes. We created enough realism to elicit novel ideas that were testable and would readily scale up to a distributed game environment. Players clearly wanted to play, they wanted to win, and they were more than willing to talk about the experience. We found that individual motivation and friendly rivalry sparked incentive to meet the mission objectives and pursue successful employment strategies. Subsequent player comments and feedback were triggered by their play experience. Accepting the limitations of a game environment is critical. ESP scenarios are admittedly crude, yet we gained important operator feedback at an early phase of development at extremely low cost.

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V. RECOMMENDATIONS AND CONCLUSION

The study we conducted for ESP is not without its limitations. ESP itself is currently at the conceptual stage, and in our attempt to determine how it should function and what expectations we might reasonably have of the eventual system, we used surrogates that are similar to but not exactly what ESP is envisioned to be. We must address any artificialities and limitations imposed by those surrogates, be they systems or processes. Those limitations invite further study to explore the possibilities for collecting player feedback and input toward bettering a future capability. Despite limitations, we were able to compile several cogent recommendations for the development of the ESP framework as the Army continues to pursue ESP as a process and set of tools.

A. STUDY LIMITATIONS

The structure of the study itself had limitations that affected the types and quality of data we were able to collect. There was no control group to compare what kind of feedback could be elicited from a traditional focus group discussion for Wingman in contrast to the feedback that was accumulated during and after playing the scenarios. Based on the time available for the game trials at NPS, if a focus group comparison is conducted in the future, the time for game play will need to be reduced so as not to deter participants by imposing a significant time commitment. Incorporating the focus group would have to be a between group design, not a within group design because of the learning effects inherent in the study.

Furthermore, the nature of the study we conducted did not allow for us to draw conclusions about how play would be accomplished and data collected in a truly distributed game environment. To assess a semblance of true distribution in a lab environment, player communication would need to be restricted to VOIP using headphones and speakers without the ability to observe the screen, verbal observations, or physical gestures of peer players. Actual physical dispersion does not allow for physical assessment of other players, either peer or opponent. Our players did not know each other personally in most cases, but they were aware of the others' status as a military officer

and may have made inferences about the other players competence based on that information. We cannot completely discount the effect of the military rank of our players, but we noted very open discussions with lower ranking players freely contradicting higher ranking officers (respectfully) without hesitation. We felt the effect of rank was minimal, if present at all. Beyond sizing up the competition, being able to rapidly address and troubleshoot connectivity, sound, or other technical challenges in a close environment in the lab will not emulate the myriad of connectivity issues that could arise for actual players on a distributed network.

The data collection methods we employed for the NPS study are insufficient to mimic data collection possibilities in a distributed game environment. We collected voice recordings and VBS2 after-action play data and play-back. Recorded voice data is cumbersome to analyze manually. Analysis of voice data in a distributed game environment is possible but faces the challenge of players being reluctant to agree to being recorded. Any data collected would require parsing recordings for key words, and the results obtained for analysis may fall short of the effort required to identify potentially relevant information. A better method of data collection would mirror the techniques used by Microsoft with their data collection from specific data fields instrumented into Xbox games and streamed back from on-line players. A joint effort between S&T researchers and the assigned program office would be necessary to determine the elements critical for collection to avoid archiving volumes of unnecessary data could not realistically be analyzed. A follow-on study could set critical information triggers in the scenarios for further evaluation. For example, in the scenarios we used for Wingman, APD navigation would be a useful data point and it could be assessed by capturing route data characteristics such as time and distance on-road or over terrain. Phase lines could be set to trigger an indicator of when they are crossed during game play indicating a player's eagerness to approach the OPFOR position or willingness to cede space or time for some other advantage. Other measures that could be implemented are use of avatar, use of sites and view perspectives, choice of weapon, and position, time, and frequency of weapons engagement.

Another data collection method we employed was the use of a post-play group interview and survey. Surveys could be automated and put on-line but might not see high participation levels if completion is optional for players. The in-person interview would not be readily available in a distributed environment. However, the proposed method for ESP to bridge this gap is to open a forum for player interaction where players could post results and feedback. This forum or forums would be an ideal venue for S&T representatives to review and incorporate recommended system or scenario modification for future play opportunities. We designed this study under the assumption that the quality and quantity of data collected would be directly aligned with the ease of which it was given. Speaking is easier than writing. Players are more willing to voice a concern than they are to write it, especially if it involves a detailed description. Furthermore, many of the suggestions we received involved a "back and forth" between the interviewer and the player to extract the idea mainly because it may have been unclear in the mind of the player at the time. Through a question-and-answer format, the idea solidified and was able to be presented for further discussion. The active maturing of an idea through question-and-answer sessions occurred several times throughout the study.

Limitations aside, our study contributed to the conclusion that relevant information can be collected from game play. Although some of the data we collected was in an artificial form due to the limits of the study, we know that useful data is there. The challenge now is to find ways to extract it in a distributed and passive format that can feed powerful game analytic processes resulting in useful information never available prior to the ESP concept. That information will be useful for decision-makers tasked with developing systems that warfighters will employ in future military operations. Furthermore, we were also able to open up a line of communication to a group of warfighters and, from that exchange, develop recommendations for the successful development of ESP as a process and set of tools for the DOD.

B. RECOMMENDATIONS

ESP has a place in the future of DOD acquisition. ESP is a means to collect valuable input and feedback from warfighters and deliver it to decision-makers within

DOD programs early in the acquisition process and with relevant mission context. The contributions of warfighters can positively impact development of future systems.

Despite a lack of overwhelming quantitative data to support prototyping as a means to reduce program cost and schedule creep, the ability to consider requirements and alternatives provides a program manager a useful tool that supports mitigation of risk throughout the acquisition process. A virtual environment offers one way to make prototyping practical and cost-effective early in the life cycle of any system. Before the fidelity of refined physical attributes and precise measurements needs to be established, a game environment offers an opportunity to reach masses of potential contributors and also to collect and quantify their inputs in a feedback loop with S&T and the program office.

The game environment must be widely available and must be accessible without substantial technological leaps by the user. Ideally, the ability to launch directly from a web browser would allow the easiest access for the broadest population of users. Although the application should be easy to launch, access should be limited to DOD users. Having a common access card (CAC) enabled site or the ability to initially gain access using a CAC and then subsequent access could be made using a username and password/code/phrase. As established programs are fielded, perhaps the DOD-only restriction could be lifted to allow for broader access beyond the DOD to look at novel use cases for or modifications to existing equipment that might apply within or outside the military domain.

Although the objective of ESP and its iterations for acquisition programs is not entertainment, the quality of game must be somewhat comparable to commercial games. One of the benefits of ESP is the ability to bring in mass quantities of data, and without a superior interface and virtual environment, potential users will spend their time doing other things outside of running proposed equipment through prescribed scenarios. Much like other modern, popular games, the environment needs to be networked to other players in real time and return a data feed for further evaluation.

The ability to network also lends to the instrumentation of the game environment for data collection and the return of that data to S&T representatives for analysis. Instrumentation of the games will be critical so as not to overwhelm researchers with data that might lend to superior commercialization of the game environment but does not contribute significantly to the development of the technology solution or weapon's system being evaluated. A discussion forum would be a valuable collection site to gather feedback for both the game and the system under evaluation. A discussion forum will also facilitate collaboration between players and observation of the tactics and techniques that might arise from such collaboration.

A key concept that we were not able to explore sufficiently in our study was the possibility of modifying the scenarios and/or the systems being evaluated. Having the ability to modify the proposed technology or equipment is essential to accumulating relevant feedback from the crowd of warfighters contributed to the effort within the ESP framework. Being able to change the scenario itself also offers an important opportunity to observe variant tactics and techniques, but must be done judiciously so as to ensure the existing data collected remains compatible with successive data collection efforts when necessary.

ESP should be considered an enabling capability and not a mandatory requirement for fulfillment by a major defense acquisition program (MDAP) to proceed to subsequent acquisition milestones. Ideally, ESP can be inserted pre-Milestone A to support a holistic ERS effort to manage risk using modeling, simulation, and tradespace analysis with the benefit of gaining mission context for the proposed system.

C.   CONCLUSIONS

The warfighters of the future will require more, not less, technological innovation to keep pace with allies and maintain a competitive advantage against potential adversaries. USD(AT&L) Frank Kendall recently stated, "If the U.S. military wants to stay No. 1, then it can't rely on the private sector to fund cutting-edge, military-specific R&D. No matter how much you reform," he said, "such weapons programs will still take many years and taxpayer dollars" (Freedberg, 2014, para. 4). Engineering innovative and

resilient systems for the future will require new technique to maximize effectiveness. ESP can aid in the evaluation of CONOPs and help to build context for the proposed mission of the system in development. ESP offers an opportunity to explore the realm of the possible, linking capabilities to outcomes, in the inexpensive tradespace of a virtual environment linking proposed capabilities to possible outcomes. Most importantly, the ability to seek and incorporate the input of the large, diverse, and experienced body of warfighters offers an opportunity to collect a trove of data unsurpassed by current techniques.

Gaining access to warfighters and their potentially groundbreaking contributions is not an insignificant task. Games are a serious option to consider for the accumulation of relevant data that will be useful to decision-makers developing future DOD systems.

ESP is not a singular solution with ambitions to rectify the inefficiencies of the DOD Decision Support Framework. Rather, it will be a valuable component to maintaining a technological advantage as the DOD pursues innovative solutions to meet warfighter need into the future.

D.   FUTURE WORK

A plan for a future study at NPS is being considered to conduct a comparison of information and feedback that can be gained from a directed focus group as compared to the feedback that can be collected from game play. Additionally, incorporating simulated dispersion will be accomplished to garner feedback from service member players on their perceptions of playing with new technologies in a distributed environment without having their in-game peers sitting beside them. The simulated dispersion will be accomplished using headsets to give players the feel of how play would be conducted off duty with other players from around the country. The study would continue to evaluate how a player might actually operate with the system being developed and assessed within the scenario to see what kind of information could be gathered from additional game play.

Collecting data useful for analysis will be nontrivial as ESP moves from a controlled laboratory to a distributed setting. The Army is conducting follow-on testing on a larger scale with a pilot planned for November 2014 where 30 soldiers from the

Brigade Modernization Command at Ft. Bliss, TX, will be playing scenarios to evaluate proposed future technologies. With a more robust and distributed system in development, the pilot test and a subsequent larger test with 100 soldiers playing will be conducted using VBS3 at the game platform. The technologies to be assessed are tactical airdrop and a coded spot laser. The conduct of the pilot and larger study will follow the general framework used in our study but will be conducted with groups of enlisted Army soldiers at a base simulation center. The continuing study will explore what kind of information can be obtained and whether it will be useful for the proposed systems being evaluated in the game environment.

The next steps will be to increase how players customize the system being developed and assessed in ESP and to move to a distributed framework with instrumented scenarios to gather and analyze game data. Ultimately, the ESP concept will enable the DOD to put warfighters at the center of capability and concept development to continue the tradition of technological dominance over adversaries into the future.

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APPENDIX A. FY2015 BUDGET DATA AND HISTORICAL DATA

The following figures and text are from the *2014 Annual Report* on the Performance of the Defense Acquisition System (USD[AT&L], 2014)). Figure 18 was also displayed in Chapter II and shows how the president's 2015 budget request was broken out by fund category. Figure 19 shows an increase in military budgets, including RDT&E in the first decade of the 21st century followed by a post-war decline in funding. RDT&E is detailed in Figure 20.

NOTE: Budget amounts are in billions of then-year (unadjusted) dollars. OCO is not included. "MilCon" is Military Construction.
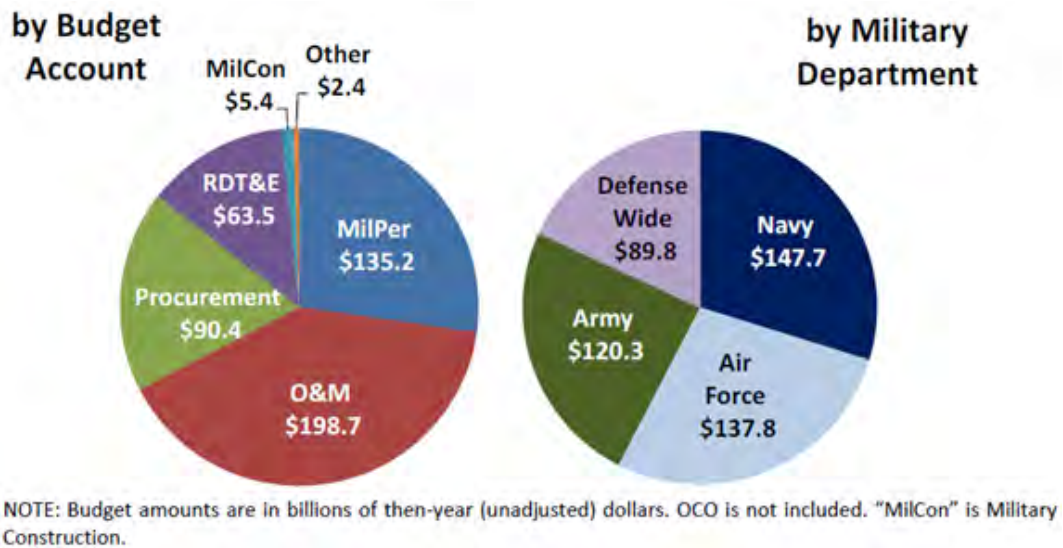
Figure 18.   Defense Budget Breakouts in 2015 President's Budget Request
(from USD[AT&L], 2014, p. 2)
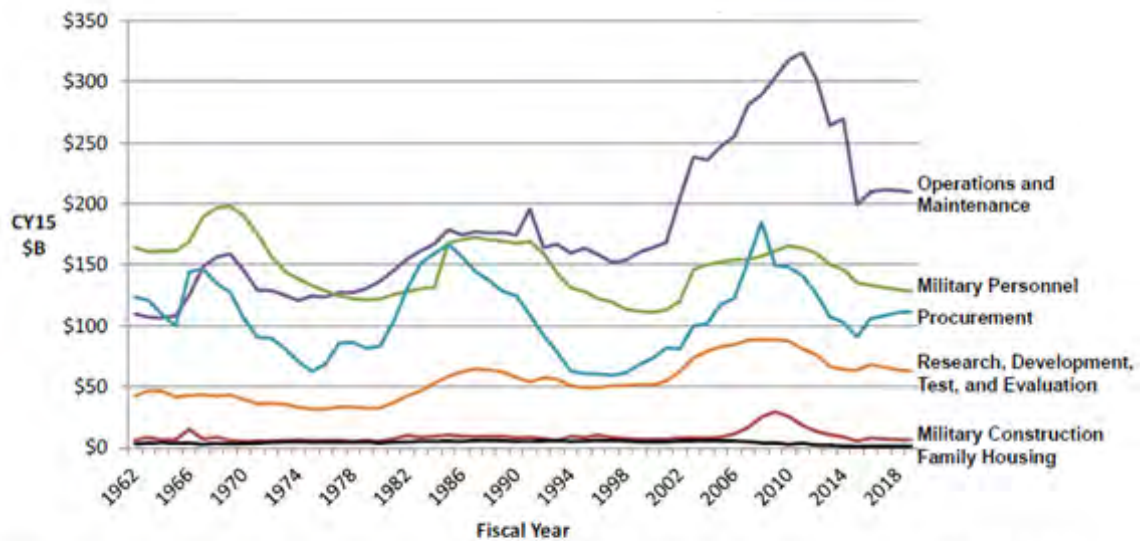
NOTE: OCO is included in fiscal year budgets before FY2014 but not in the current fiscal year (2014) or in the FY2015 President's Budget figures (FY 2015–2019). Budget amounts are adjusted for inflation and reported in billions of calendar year 2015 dollars (CY15$B).

Figure 19.   Defense Budget Accounts: Historical and PB15 (FY1962–
FY2019) (from USD[AT&L], p. 2)
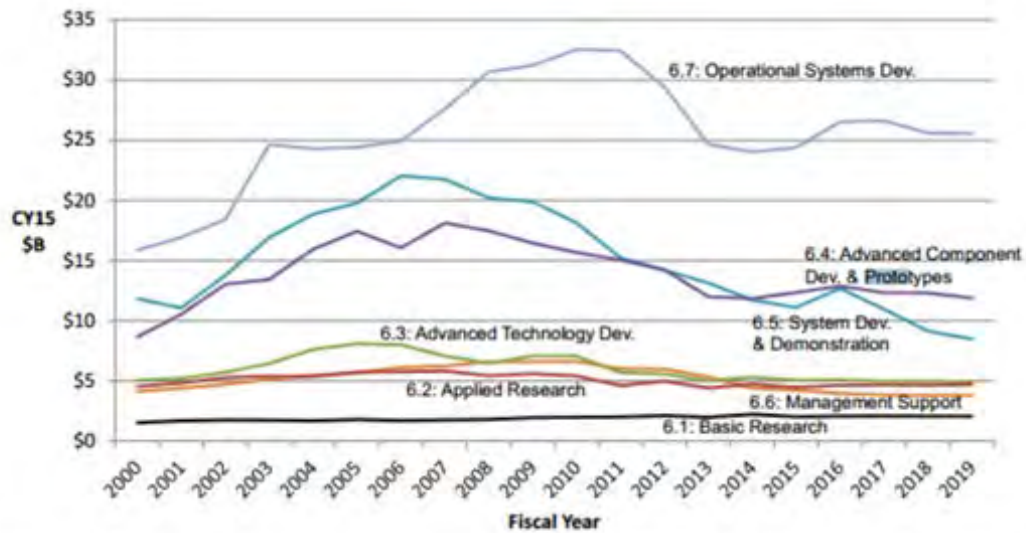
NOTE: OCO is included in fiscal year budgets before FY2014 but not in the current fiscal year (2014) or in the FY2015 President's Budget figures (FY 2015–2019). Budget amounts are adjusted for inflation and reported in billions of calendar year 2015 dollars (CY15$B).

Figure 20.   Recent and Projected RDT&E Budgets as of PB2015 (FY2000-FY2019) (From USD(AT&L), p. 3)

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APPENDIX B. ENGINEERING RESILIENT SYSTEMS
AND THE DEFENSE ACQUISITION SYSTEM

More complete and robust requirements

Engineering design process more efficient & effective

75% reduction in time to complete systems by reducing rework

Integrated producibility and lifecycle concepts across acquisition process

Establish baseline resiliency of current capabilities

100-fold increase in # of parameters and scenarios considered in setting requirements

Explicitly consider manufacturability and affordability of proposed design(s)

Quantified adaptability to changing mission requirements

◇ = Decision Point

▲ = Milestone Review

Risk management accomplished via combination of high fidelity modeling, simulation, tradespace analysis, and the inclusion of mission context assessment

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APPENDIX C. EARLY SYNTHETIC PROTOTYPING

Acquisition professionals (1) use scenario editing tools to develop concept ideas for testing. These are playable scenarios (2) that are instrumented with metrics of interest (e.g., system selected, rounds fired, speed attained, distance traveled) specified by the program office. These scenarios are made available for play via a game server (3) that allows distributed warfighter players (4) to play, capturing diagnostic information. Communities of players are coordinated via conventional social media (5). Players can modify scenarios locally. ESP does not assume the best scenarios will come from the program office. More likely, the best ideas will be modifications of those ideas made by players. Game-play diagnostic data (6) and modified scenarios (7) are returned to the server and then to the program office (8). Program offices can also interact with players via the community (9). Science and technology programs (10) will use ESP to test new ideas at minimal expense before follow-on larger investment. They will also use ESP to demonstrate concepts to potential transition customers (11) to obtain buy-in early, which will facilitate an increase in successful transition to programs of record.

Figure 21.   ESP Schematic (from Murray et al., 2014)

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APPENDIX D. EARLY SYNTHETIC PROTOTYPING TRIAL GAME SESSION SCRIPT

Welcome Comments: Thank you for agreeing to participate in our study. Introductions.

The purpose of the study is to determine how game environments might be used to explore novel design concepts early in the acquisition cycle.
The Army is calling this concept Early Synthetic Prototyping.

For our study, we will be using a robotic vehicle called Wingman. Wingman can be equipped with a variety of weapons, armor, and engines that changes the firepower, vulnerability, and speed and agility of the vehicle. We will be using some pre-configured versions in our testing and they are referred to as autonomous platform demonstrators (APDs).

We are going to start with a familiarization scenario so that everyone can become comfortable with how the keyboard and mouse are used to control your character and vehicle. Once everyone is comfortable, we will start the three main scenarios. For each of the three scenarios, there will be a blue team. For the second and third scenarios, there will also be a red team. The blue team will have a specific mission objective and will be given access to one or more Wingman vehicles with which to accomplish that mission. The red team's objective is always the same—destroy the blue team.

Before each mission, we will read you the mission parameters so you know specifically what you are asked to do. We will separate red from blue so that each team can privately discuss how they intend to accomplish their goals. When both teams are ready, we will begin the scenario. We are recording the sessions so please talk aloud so we can hear what you say. We can restart a scenario at any time or we can repeat a scenario if you wish to try it again. During a scenario, we can answer any question regarding the game interface but we will not answer questions or hint about how to win the scenario.

We want you to play as much and as often as you would like. We can extend today's session if time permits or have you return for another opportunity to play. Please be patient as you and your peers try to learn the game; it will be challenging if you limited game experience. And, it will be different than other games you have played before.

Before and after each scenario, we will pause ask you some questions. We request that you wait for instructions while in the game to ensure we are set to proceed.

Remember, Wingman is a concept. It doesn't really exist. Assume the Wingman Program Manager is sitting right here.

What would you tell him about the vehicle itself or how you would use it?

Are there missions we did not explore here for which you think it might be an effective asset? This study is about whether game play can inform the early acquisition process. Tell us what you think.

<break>

Informed Consent

Before we begin, we need to ask that you read and sign this informed consent form which states that you are voluntarily participating and that we can record what you say and do for the purposes of this study only.

DLI: Army Behavioral Health Clinic contact info: (831) 242-4328

Questionnaire [Demographics at the beginning]

Next, please fill out this short demographic questionnaire so that we know a little about your experiences and game playing history.

_____

In VBS2

Basic game navigation:
       The VBS2 Platform is used to provide a first person shooter gaming environment in which to demonstrate employment of the various APDs in different terrain and tactical employment scenarios. The first scenario gives the opportunity for user familiarization. More specific information on each scenario follows in the subsequent section.

VBS2 - Infantry Controls Walk through keyboard map
Movement keys
  W: Forward; W+Shift: Run; W+W: Short Sprint
  S: Backward
  A: Left   D: Right

Weapons Keys
  R: Reload   V: Optics view
  I: Open gear menu   +/-:   Zoom in/out
  Control +shft: on/off safe

VBS2 - Vehicle Controls (See Reverse of keyboard map)
  +/-:   Zoom in/out
  Enter: 3d Person View   Tactical View
  N: Vision Mode (Important for visibility)
  L: Lights ON/OFF (Important for visibility)
  U: To enter the APD view and navigate the ADP

Aim the Turret using the mouse; Fire the APD mounted weapon with the mouse (Left Click)
Scroll wheel: scroll through menu of available options to interact with the vehicle
 Esc: to reach option to abort scenario

APD Options:

APDs are outfitted with a level of armor, a weapon or weapons, a set engine power, and a maximum speed. These four factors can be weighed to determine which type of APD is more appropriate for the job. During today's trial you will be able to employ the follow APDs:

APD 25mm / 7.62
APD M134
APD Speedy

Autonomous Platform Demonstrators (APD)

APD 25mm / 7.62mm
- Armor: 200
- Weapons: M240, M242 Bushmaster
- Engine Power: 600
- Max Speed: 80

APD Speedy
- Armor: 100
- Weapons: M240
- Engine Power: 2000
- Max Speed: 40

APD Balanced
- Armor: 200
- Weapons: M240
- Engine Power: 600
- Max Speed: 50

APD Heavy
- Armor: 300
- Weapons: M240
- Engine Power: 400
- Max Speed: 60

APD .50Cal
- Armor: 200
- Weapons: M2 Browning
- Engine Power: 600
- Max Speed: 80

APD Mk19
- Armor: 200
- Weapons: MK19
- Engine Power: 600
- Max Speed: 80

APD M134
- Armor: 200
- Weapons: M134
- Engine Power: 600
- Max Speed: 80

APD ARAS 50
- Armor: 600
- Weapons: Lethal/Nonlethal 50 ball
- Engine Power: 800
- Max Speed: 70

APD SSADT
- Armor: 600
- Weapons: Active Denial System
- Engine Power: 800
- Max Speed: 70

APD ARAS 7.62
- Armor: 600
- Weapons: Lethal/Nonlethal 7.62 ball
- Engine Power: 800
- Max Speed: 70

APD TOW
- Armor: 200
- Weapons: TOW Launcher, Hellfire Launcher
- Engine Power: 600
- Max Speed: 80

APD - Boomerang
- Armor: 200
- Weapons: TOW Launcher, Hellfire Launcher
- Engine Power: 600
- Max Speed: 80

<u>Training scenarios – training navigation</u>
Click on APD Navigation
This can be run multiple times if needed for all players to become comfortable.
Click Start

Basic weapons training requires you to:
Gain control of an APD remotely.
Navigate through an obstacle course and eliminate any targets encountered.

Double click on the notepad at the top like the spirals to reduce its size.
Scroll using the mouse wheel to zoom in or out of porto.
Because this is training, the map does not show your objectives.
This training scenario is not networked so others won't be visible.
Click continue
Click M to reach the map to get oriented to where you are in Porto.
M again will return you to the scenario

Look for the yellow cue on the screen to take you to your first objective.
Pick up the AT-4: engage the HMMWV with the AT-4 or the M-4
Use V to site in and Left click to fire

Scroll wheel get APD controller
Select an APD; Choose APD 134 or APD25mm/7.62
Hit U to get the APD view.
Scroll to screen
For ease of navigation we recommend keeping the weapon barrel between the track to ensure your visibility matches your movement; Your view will always be where you weapon is directed.
Hit the +/- keys to zoom in or out.

In the training navigation, follow the yellow arrow cues to meet your training objectives.
If you "dismount your APD" and return to your character you will start over.

Questions:
Do you want to play again?
How do you think you did?
What do you think you could do to improve your performance?

We can continue playing or set up another session.

Scenario 1 – APD Chase (Ensure server is set to Takistan and Chase)

Go to networking; There is one network game session available.
 Select the player that corresponds to your station number.
        Take note of the verbal orientation provided next to the role.
        Ex. 1-1-A-! POS Hillside, south of main road
        Blue1 select player BLU 1, etc.

Now that everyone has the APD Chase scenario up on their screens, let's take a moment to get oriented. The scenario and objective is (Read objective for APD Chase):
 Scenario: Recent Intel suggests A HIGH-RANKING OPFOR OFFICER is currently in the area of Takistan, although his exact whereabouts is unknown. A convoy in the small village of Hazar Bagh is set to meet him. Using your APDs, follow the convoy without being seen. When contact with the target is made, eliminate him, all units supporting him, and the convoy.

 Click the arrow on the notepad to see objectives to meet for game success:
        a. Remain under cover and avoid detection.
        b. Eliminate OPRFOR once contact with the target is made
        c. No APDs can be destroyed.
Find your APD on the screen: It should correspond to your station number.
        a. Click on the hyper-linked name on the notepad
        b. Zoom in and out by scrolling the mouse wheel
        c. For a larger view, minimize the notepad by double-clicking near the top spiral.
        d. You can manipulate the map view to get a better orientation by sliding the mouse.
Feel free to discuss the scenario and work a plan among your team (3-5 min).

We are interest in your estimate of the situation and a brief outline of your plan to meet the objective.
        - With the limited information available to you, what is your estimate of the situation?
        - What is your plan:
            How do you think you'll employ your APDs?
            How will you employ your characters?

All players hit continue; Then, server hits continue

Scroll: select UGV Controller - This is your person view
  U: To enter the perspective of your APD
  Scroll: Select Screen—scroll again to change optics
  N: Optics view; L: Lights

Click continue. (Click continue on the server to start the scenario)
[Server: exit out and start a new host session]

Scenario 2 – APD Attack (Ensure server is set to Geotypical Eastern Europe and Attack)

Two Red Players will move to LabA.

Go to networking; There is one network game session available for players.
 Select the player that corresponds to your station number.

Take note of the verbal orientation provided next to the role.
> Ex. 1-1-A-! POS Hillside, south of main road
> Blue1 select player BLU 1, etc.

BLUFOR Objective You must rescue the prisoners from the OPFORs, but the camp is heavily guarded. You each have an APD, but most of the EN are armed with rocket launchers, so a direct assault will not work. The prisoners will start running to freedom once the shooting begins, but the OPFOR will shoot at them as they run away.
Rescue as many prisoners as possible. Eliminate all of the OPFORs.

OPFOR Objective Two BLUFOR operatives with APDs are attacking. You must stop them from freeing the prisoners, but do not shoot the prisoners, even if they have escaped.
Eliminate both of the BLUFORs

Feel free to discuss the scenario and work a plan among your team (3-5min).

We are interest in your estimate of the situation and a brief outline of your plan to meet the objective.
> - *With the limited information available to you, what is your estimate of the situation?*
> - *What is your plan:*
> > *How do you think you'll employ your APDs?*
> > *How will you employ your characters?*

Click continue.
 (Click continue on the server to start the scenario)

M134 does not have a long barrel; recommend zooming out to see perspective of APD.

Scenario 3 – APD Defend (Ensure server is set to Porto and Defense)

Two Red Players will move to LabA.

Go to networking; There is one network game session available for players.
Select the player that corresponds to your station number.

Take note of the verbal orientation provided next to the role.
> Ex. 1-1-A-! POS Hillside, south of main road
> Blue1 select player BLU 1, etc.

BLUFOR Objective Defend your position from OPFOR units for 5 minutes. Each of you have an APD under your control. If the APD is destroyed, you will lose 5 points and the APD will automatically respawn in its original positions. If either player dies, you will lose 10 points and the enemies will all be reset to their original positions. Rescue as many prisoners as possible.

OPFOR Objective Seek and destroy the BLUFOR units and vehicles for 5 minutes. Every time a BLUFOR player gets killed, you will be respawned in one of your three start positions. If a BLUFOR APD gets destroyed, it will respawn at its start position. If you die, you will automatically get respawned on one of your starting positions.

Feel free to discuss the scenario and work a plan among your team (3-5min).

We are interest in your estimate of the situation and a brief outline of your plan to meet the objective.
> - *With the limited information available to you, what is your estimate of the situation?*
> - *What is your plan:*
> > *How do you think you'll employ your APDs?*
> > *How will you employ your characters?*

Click continue.
 (Click continue on the server to start the scenario)

Post - Run verbal group interview

Is anyone feeling any adverse impacts from playing the game?
If yes, please feel free to remain behind and/or contact the DLI Behavioral Health Clinic at **(831) 242-4328.**

ESP Post-Run Interview Outline

WINGMAN SPECIFIC
1. What general observations and recommendations do you have about the Wingman concept?
   a. Is it useful? If so, for which scenarios? Why?
   b. Should it be configured differently? Scenario dependent?
2. How would you recommend deploying Wingman?
   a. For which missions?
   b. In which configuration?
      i. Firepower / Armor
      ii. Agility / Range
   c. How many?
   d. Who operates them?
3. What can or would you do differently with Wingman that you might not do with a person?
4. What concerns you most about the Wingman concept? (What are the greatest barriers to successful development and deployment?)
5. What are the greatest opportunities that Wingman might offer?
   a. New missions?
   b. Radically different doctrine? (e.g. all robots and no people)

ESP SPECIFIC
1. Is a game environment a suitable place to experiment with early ideas like Wingman?
2. Was the game environment "real" enough that you could explore new ideas?
3. If we provided an editor that allowed you to reconfigure the vehicle or the scenario, would that add to your interest?
4. What conclusions about Wingman do you think you can draw from playing a game?
5. What conclusions about Wingman do you NOT think you can draw from playing a game?
6. Do you think you can have an impact on how the military tactically employs its personnel or sets its equipment specifications?

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ESP Game Session Layout
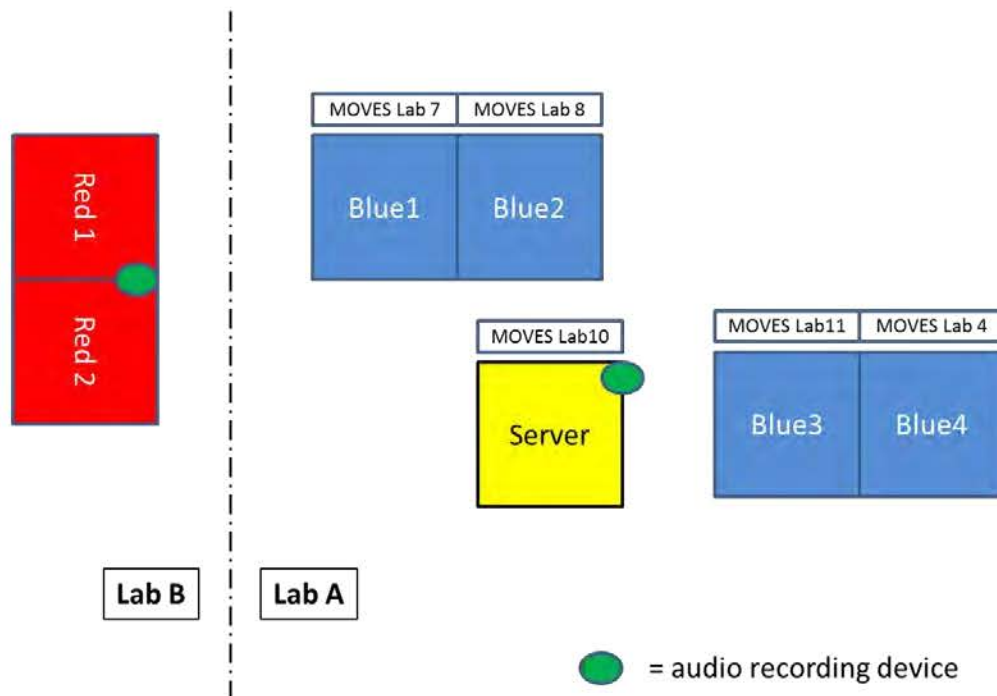
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APPENDIX F. EARLY SYNTHETIC PROTOTYPING GAME TRIAL PRE-DEMOGRAPHIC SURVEY

EARLY SYNTHETIC PROTOTYPING PARTICIPANT QUESTIONNAIRE

1. What branch of service are you affiliated with? _____

2. What is your status (circle one)?   Civilian (skip to c) / Active Duty / Reservist

    a. What is your rank? How many years of service do you have?

    _____/_____

    b. What is your MOS / Branch / Rate / Community designator?

    _____

3. Do you have prior video gaming experience within the past two years?

    Yes / No

    a. How much (circle one)?

        < 1 hour per week

        1-2 hours per week

        2-5 hours per week

        > 5 hours per week

    b. Is your gaming experience with first person shooter games? Yes / No

        1. List a few of your favorite games (of any type)

            a. _____

            b. _____

            c. _____

            d. _____

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APPENDIX G. EARLY SYNTHETIC PROTOTYPING GAME TRIAL POST-PLAY SURVEY

Participant Survey

Knowing that your participation contributes to the Early Synthetic Prototyping concept and the Wingman project, do you feel that your time was spent effectively today?

Effective	semi-effective	Neutral	semi-ineffective	Ineffective
1	2	3	4	5

If yes, how?   If no, why not?

_____

What kinds of ideas do you have for future concepts or equipment?

_____

future tactics?

_____

future doctrine?

_____

Other ideas?

_____

Would you contribute to future efforts to develop or test ideas in a game environment?

Likely	Somewhat Likely	Neutral	Somewhat Unlikely	Unlikely
1	2	3	4	5

If no, why not?

_____

Would you encourage others to participate in future efforts to develop or test ideas in a game environment?

Likely	Somewhat Likely	Neutral	Somewhat Unlikely	Unlikely
1	2	3	4	5

_____

Do you have any ideas, recommendations, or suggestions for Early Synthetic Prototyping?

_____

Do you have any ideas, recommendations, or suggestions for Wingman?

_____

Would you play this game, or one very similar to it again?   Y or N

How often would you play this game if you had access?

Access via download to a personal device: #_____**times per** week/month/yr

Access via the internet: #_____**times per** week/month/yr

Access and time at work: #_____**times per** week/month/yr

Wingman Autonomous Platform Demonstrators (APD)

Mobility:

What is your opinion on the mobility of the APD?

| Effective | semi-effective | Neutral | semi-ineffective | Ineffective |
| 1 | 2 | 3 | 4 | 5 |

_____

How would you modify the APD's mobility?

_____

Armament:

What is your opinion of the APD's armament?

| Effective | semi-effective | Neutral | semi-ineffective | Ineffective |
| 1 | 2 | 3 | 4 | 5 |

_____

How would you modify the APD's armament?

_____

Optics:

What is your opinion of the APD's optics?

| Effective | semi-effective | Neutral | semi-ineffective | Ineffective |
| 1 | 2 | 3 | 4 | 5 |

_____

How would you modify the APD's optics?

_____

VBS2 employment?

Were you able to navigate the APD within the scenario?

_____

What challenges or positive attributes do you have regarding the movement and views within the game environment?

_____

Do you think the APD is a realistic asset for employment by the military? Yes or No? Why?

_____

Scenario Feedback -- NAVIGATION

	yes	most	some	few	none
Did you understand the scenario objectives? 1 2 3 4 5

Comments:

_____

Did you meet the scenario objectives?

yes most some few none

1 2 3 4 5

Comments:

_____

Would you play this scenario again if given the opportunity?

yes most some few none

1 2 3 4 5

Comments:

_____

Did the game environment (VBS2) make it easy or difficult to reach the objectives?

Easy   Somewhat Easy   Neither   Somewhat difficult   Difficult

1   2   3   4   5

Comments:

_____

How did you communicate with your teammate in this scenario, was it effective? Would you change your communication strategy?

_____

Did this scenario and the game environment give you the opportunity to produce a creative solution to meet your objective?

yes most some few none

1 2 3 4 5

Comments:

_____

Scenario Feedback -- APD CHASE

	yes	most	some	few	none
Did you understand the scenario objectives?	1	2	3	4	5

Comments:

_____

	yes	most	some	few	none
Did you meet the scenario objectives?	1	2	3	4	5

Comments:

_____

Would you play this scenario again if given the opportunity?

yes	most	some	few	none
1	2	3	4	5

Comments:

_____

Did the game environment (VBS2) make it easy or difficult to reach the objectives?

Easy	Somewhat Easy	Neither	Somewhat difficult	Difficult
1	2	3	4	5

Comments:

_____

How did you communicate with your teammate in this scenario, was it effective? Would you change your communication strategy?

_____

Did this scenario and the game environment give you the opportunity to produce a creative solution to meet your objective?

yes	most	some	few	none
1	2	3	4	5

Comments:

_____

Scenario Feedback -- APD Attack

	yes	most	some	few	none
Did you understand the scenario objectives?	1	2	3	4	5

Comments:

_____

	yes	most	some	few	none
Did you meet the scenario objectives?	1	2	3	4	5

Comments:

_____

Would you play this scenario again if given the opportunity?

yes	most	some	few	none
1	2	3	4	5

Comments:

_____

Did the game environment (VBS2) make it easy or difficult to reach the objectives?

Easy	Somewhat Easy	Neither	Somewhat difficult	Difficult
1	2	3	4	5

Comments:

_____

How did you communicate with your teammate in this scenario, was it effective? Would you change your communication strategy?

_____

Did this scenario and the game environment give you the opportunity to produce a creative solution to meet your objective?

yes	most	some	few	none
1	2	3	4	5

Comments:

_____

Scenario Feedback -- APD Defend

	yes	most	some	few	none
Did you understand the scenario objectives?	1	2	3	4	5

Comments:

_____

	yes	most	some	few	none
Did you meet the scenario objectives?	1	2	3	4	5

Comments:

_____

Would you play this scenario again if given the opportunity?

yes	most	some	few	none
1	2	3	4	5

Comments:

_____

Did the game environment (VBS2) make it easy or difficult to reach the objectives?

Easy/supported effort	somewhat	Neither supported or prevented	somewhat	Difficult/prevented effort
1	2	3	4	5

Comments:

_____

How did you communicate with your teammate in this scenario, was it effective? Would you change your communication strategy?

_____

Did this scenario and the game environment give you the opportunity to produce a creative solution to meet your objective?

yes	most	some	few	none
1	2	3	4	5

Comments:

_____

APPENDIX H. SUMMARY TRANSCRIPTION OF POST-GAME INTERVIEW (PILOT)

Pilot:
Bounding overwatch for the chase scenario; lights were problematic for networked scenario.
Concern expressed over whether a tracked vehicle was appropriate for this mission.
Attack:
Blue Plan/execution—anticipated a wall around the prison. Intended to rendezvous on the north side. AI took over the APD and conducted an unintended frontal attack.
Red Plan/execution—Intended to take out the operators rather than the APDs. Player was taken out because he was unable to move quickly enough in game environment to aim, shoot, and move to safety. Other red player noticed the smoking APD and sought the operator but was noticed by the BLUFOR first. Wounded, he wasn't able to move. Noticed the APD moving around the perimeter and "hid" by a tree. Shot RPG and AK rounds. Saw the possibility to employ APD as a vehicle borne improvised explosive device (VBIED) or mobile mine. "Dead" comrade was able to observe the movement of the BLUFOR so he knew approximate location. Red player was successful with a long distance shot. Small arms were the deciding factor
Defend:
Red plan—whoever was spawned initially in town would support by fire long range. They didn't realize they would have AI players. Re-spawn was problematic because in the middle of aiming, the player would re-spawn to origin. The situation dissolved to chaos because they weren't able to maintain aim and make effective use of their shots.
Blue plan—eyes in multiple directions to observe full fields of view. Players were hiding in grass behind the compound in an attempt to maintain safety.
Which scenarios did they like?
- Chase. Compared to an unmanned aerial vehicle (UAV) recon and give Predator permission to shoot. The Red team also liked the Attack scenario because they were successful. Blue like APD Chase. Both teams did not like the defend scenario due to the constant re-spawn and disorientation.

Vehicle?
- Wheeled vehicle appeared like a normal tactical vehicle. Situational awareness of whether lights were on or off. The menu interfered with the observation of the screen command.
- Recommend simple radio buttons present along the border of the screen to indicate on/off and be able to manipulate the state as well. The scroll wheel was a challenging way to find out the "state of the system."
- Training didn't give all the screen options. (This was later corrected by providing additional direction during the familiarization scenario.)
- Recommend drop waypoints to allow vehicle to auto-drive to a particular location and then the operator could gain situational awareness by observing through the turret rather than have to navigate and observe simultaneously. Having a decoupled turret view is spatially disorienting.
- Drive mode—lock the gun position to the front. Big screen becomes drive screen and the small screen becomes the turret screen.

- Two operators recommended: one operator for the robot, one soldier/Marine. Comparison made to Halo.
- Treat this like a UAV—doesn't need an operator adjacent to it as long as we are capable of communicating with it. There could be two operators with one person navigating and moving and the other able to target and make use of observations. Waypoints would be useful. Trees and obstacles presented challenges to movement and observation. Player questions robustness of vehicle considering environmental challenges.
- Toggle between views—drive view or turret view based on the task to be accomplished. Navigate, drive, aim, shoot is challenging for a single person.
- Players would prefer a game pad rather than keyboard.
- Personalized auto-settings like "pre-mission," "tactical-night-mode," "tactical-day-mode," "non-tactical-night," "non-tactical-day," etc. to avoid the situational disorientation involved in coming into the scenario.
- Example of turret indicator feature for tanks in relation to the hull. (This is a feature available on different APD versions.)
- Operator is not just going to fall-in on a piece of equipment. The operator would be far more familiar with the system's capabilities and able to tweak the settings prior to embarking on the mission.
- "Tactical-day" and "tactical-night" settings so the players could customize from there.
- Zoom and perspective—recommended farthest out zoom.

What kinds of tactical tasks could you accomplish with wingman?
- How much do you trust it? Performance. If there is another controller in the vicinity that the human can interact with the trust level would be higher than an operator out of sight with whom you could lose communication or a fully automated system. Fear of hacking.
- Armored platform with gun: support by fire, reconnaissance. Not concerned about it being killed. Not as concerned about destruction or capture.
- Perception that capability is in line with what a human can currently provide. An operator could enhance the capability but skeptical of an autonomous vehicle.
- Comparison to UAVs—trust from UAVs grew in Iraq significantly. Compared to Ravens and Shadow—initially perception was that the UAVs only saw a small picture. Current perspective is more trusted based on operator competency. Zooming and movement depends on the operator skill level. Having it operated remotely wouldn't be too much of an issue but there would be challenges with plans, contingencies, and communications. Preference for the operator to be closer to the supported unit/soldiers.

Would a game session inform ESP?
- Recommend incorporating the more specific user base.
- Challenges existing doctrine by incorporating non-standard user base to evaluate and try variant tactical employment.
- May be a tendency for experienced users to employ the asset in accordance with their experiences.
- Recommend large scale study to achieve greater consensus than small isolated sessions. Increase observations longitudinally to capture proficiency gains with the gaming environment. This would reduce the division between naïve and more proficient gamers and bring ideas from naïve and experienced tacticians into the same environment.
- This is what it should do—what else can it do?
- Clear questions—what specific features are we looking to evaluate. What was the interface like, how could it be improved.

- VBS2 is available. Networked opportunity may present challenges to collecting data. However, the ability to reach more players and attempt to achieve consensus.

Tactics? Use this environment to develop new tactics?
- Re-spawn scenario should keep people "dead" so they know the repercussions of their actions.
- Play ten rounds: Play until players are dead, take a break after each round to rehash, assess the plan, play again, repeat. Recommend overhead view for the mini-AAR.

Opportunity to select terrain and modify vehicles? Would that grab players' attention and incite participation?
- Ability to modify allows players to partake but then players might figure out ways to "game" the game and become indestructible?
- What's the aim—entertainment or practical application? Need to balance.

Conversation on incorporation of real world locations—geotypical (not geo-specific) is mostly accurate in VBS2.

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APPENDIX I. SUMMARY TRANSCRIPTION OF POST-GAME INTERVIEW (SESSION 1)

Group 1
-Enjoyed the "hunting" aspect of the attack scenario. There was time available in the scenario to get oriented and make his way around. The defend scenario was too frantic

Liked APD Attack—prison. Didn't like APD defend due to getting disoriented frequently.

Red force attempted to go around the backside but they kept getting respawned (we think this was also due to the team trying to go outside of the "bubble" of the game). Saw it as a penalty when they took out the enemy.

APD Attack—prison. Liked the terrain and being able to take various positions and be able to hide.

Recommendations for wingman?
- Insurgents didn't have technology.
- Seems like players are less connected so the players were more willing to put themselves out there. In the APD chase they kept getting caught because they weren't cautious and kept getting too close. In APD attacked, tried to get close to get a good look but the APD was quickly taken out.
- Easy target but easier to make bold moves.
- One player had major frustration with navigation and controls. The terrain presented a huge problem.
- Can't turn your head in the truck.
- You can turn the turret so you could drive and look outside of your field of view.

Which scenarios do you think the robots would be most useful?
- Defense. Can be employed like a patrol to expand your perimeter.
- You don't really care that you're putting it out there.
- You take fire but then you get information back on your adversary's location.

Vehicle modifications?
- Scenarios didn't test the vehicles to the extent that they are capable of.
- Recommend a group of 5: 3 infantrymen and 2 vehicle controllers.
- Lose big picture awareness with one person.
- Alternative would be 1 person with a vehicle and 1 person without within existing concept.
- Recommended mode of employment 5—running 2 robots at a time.
    - o Conventional employment recommended:
        - Fuel, Cl IX, … a small team would not be able to take advantage of an APD.
        - Company sized element with enough logistical back support.
        - How would you package this for a rapid deployment force?
        - Logistical pain that a foot soldier doesn't have to worry about.
        - More power in terms of supporting an APD.
        - NO rockets—loading would be a challenge and armament would be susceptible to blowing up.
        - Recommend armament along the same lines as the unit it's supporting.

- Mk19 might be challenging to employ … or, put it in defilade somewhere to use as a fire support weapons without endangering your own men.
- MK134 mini gun is small but can send a lot of rounds … but if the gun breaks down, it becomes a sensor.

Concerns about employment?
- In defense, it's a big target. Concerned about destruction of technology or not putting any sensitive equipment/information on the robot.
- Maybe a mechanized unit that could move it and fix it.
- Concerns over hacking into its network connection.
- Robot is not a person. This brings functionality but is this the right way to employ our assets.
- Multiple players were hesitant to allow for an autonomous vehicle.
- Talked about 2 people, each controlling an APD rather than 2 people controlling one APD.

ESP? Game environment for gathering ideas?
- Practical place to compile ideas
- Adapt scenarios based on weaponry.

Was game environment real enough to explore ideas?
- Limited to certain types of terrain. Example, Afghanistan is different than the terrain in the scenarios.

Editor?
- Customization— "hands down" because you can create your strategy based on the scenario with the capabilities.
  o Example: Suicide robot, or diversionary element well armored so its survivable and can take lots of enemy fire.

Conclusions for wingman different from just talking?
- Playing gave players opportunity to see and view what it can do and how to make it work.
- Cheaper in the virtual environment.
- Challenges: simulation of dust, parts, getting stuck.
- What happens when the optics fail or a battery fails or there is a leak or a track is thrown?
- Assumptions of simulation.
- Good to test a possible theory but would need real life to verify.

APPENDIX J. SUMMARY TRANSCRIPTION OF POST-GAME INTERVIEW (SESSION 2)

Group 2
Wingman recommendations?
- Trouble following re-spawn as an insurgent.

Which scenario did you like?
- Prison—both blue and red.
- Convoy—good but need to know enemy's protection range. What kind of optics they have. Otherwise, the situation kind of leads you to follow them down the road.
- Defaults to "undetectable" situation with light off.

What other settings would be helpful?
- Being able to reference location and orientation without having to jump to the map and taking you out of the scenario. More like a map—top down view in the corner of your view screen.
- Followed compass directions but had to verify where we were on the map.
- Looking for a map overview on the screen.
- Prison (Attack) was mostly a first person shooter scenario. The APD didn't really matter. Once the APDs were shot by the rocket launchers, the players were able to use the trucks.
- Red was able to observe the APDs easily over the horizon
- Going back to the Chase scenario, it doesn't seem likely that two people with two APDs would be able to get into a town full of bad guys undetected; they seem pretty loud.

Were the robots useful in any of the scenarios?
- Clumsy to use in defense. Needed to figure out how to move around, which way tracks and turret were pointed.
- There is an advantage to having a 25mm gun at your disposal but being the guy in the fight and trying to control the robot is mentally too much to handle.

For what kind of missions would the robot be useful?
- Red perspective—didn't know where shots were coming from. But the Blue team reported that they were using small arms to provide the harassing fires.

Can you see a scenario where you would use wingman?
- Defensive position.
- Blocking, outer perimeter asset.
- To hold ground without maneuvering.
- APDs to run patrols around a perimeter might be useful. The controller is not "in the fight" but is able to control the APD. Controller not exposed. From personal experience, used a UAV to run a patrol around the perimeter.

Do you see someone controlling more than one APD?
- On the contrary, I think you need more than one person to control each APD. With live ammunition, I think you need one driver and one shooter minimum. Someone needs complete situational awareness. See the risk as significant for live ammunition and controller getting overwhelmed.

Armament? Agility?
- Once players were able to control it, it was fine. It moved fast enough.
- If they took one RPG round the APD was done. Compared to an Abrams that can take several rocket rounds.
- If 20 year old armament technology can withstand a rocket launcher, the APD needs to be able to sustain the highest standard currently available.

-Players asked: What would it take to roll the APD over? Not sure if controller would be able to see what was in his way and what might cause the APD to roll over. Incline may be disorienting, the user might not be able to see the incline through the screen view.

Concerns over wingman concept?
- Lack of realism. Develop indifference to rounds coming at you.
- Player responds differently. Player would get down if incoming rounds.
- Players are more bold and reckless because they know it's not real.
- Removes some natural inhibitions in the game environment.
- Red plan was to draw fires because he knew he would get re-spawned.

Opportunities for wingman?
- Employ it like a UAV was mentioned previously.
- VSO positions—village stability operations. Supports a small team of guys with flexibility. They could do route patrols. Could be emplaced outside of perimeter. If you have the means to recover it or protect it, you could employ it on a piece of high ground that you would not otherwise own. Or, at partner checkpoints if you didn't want to leave forces to stay the night. A guy is "on watch" within safe perimeter but shows support for the mission. … Keep the turret moving. Even if it wasn't fully employed, it's a demonstration.

Novel employment?
- Depending on capabilities—armed reconnaissance where you might not want to send people out. If you can't get a UAV out due to weather, depending on sensors, armament, mobility.
- Controller needs to be "buttoned up" somewhere. You need to be in the vehicle or 100 miles away.

ESP?
- Get an idea of how equipment would behave or be used in a certain environment. Driving down a road.
- Useful to test the actual user interface—you are using the actual screen. What is the controller actually using? Toughbook or some other controller.

Was the game environment real enough to explore?
- Yes, we were able to come up with a few strategies. They didn't always work but it gave us a chance.

What if you could manipulate your APD?
- Supports the groups "buttoned up" concept rather than soldier on the group.

What kinds of things were missing from the game scenario?
- Rollover
- Noise signature—don't think it's realistic

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- Voice communication employed during the session.
- In a real life scenario if two controllers where located across an active battlespace, they may have a hard time communication given friction of radios comms.
- If two controllers were "buttoned up" they would be able to sit next to each other and communicate a plan in real time which is preferred to a radio working intermittently in an urban environment.

Would you play this online?
- Never have so I'm sure if I would do that.
- If it was reliable and didn't crash it would be practical.

Would you play in a work environment? In a sim center
- If you get tasked with a mission you have never done before. If you could set the scenario and pick your "tools" and figure out what you needed to take and what to leave back.
- Pre-mission.

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Group 3
Defend—
Attacker—orientation of where they were. The yellow queue were helpful and followed AI characters.
Sought out APDs to fire on, re-load, die, aim, load, fire for each re-spawn
Both Red and Blue had AI but Blue AI avatars help the effort considerably.
** There was a guy on the roof. Tried to take cover; as soon as he got the UGV controller, the character stood up so he was fully exposed and easily shot.
Once the avatar found a "safe" spot, the APDs were killed and re-spawned before control could be established. Turned in a "spray and pray" rather than clear engagement.
Offense (defense) would have been mobility. Not a good idea to sit right in front of the base. There wasn't sufficient time after re-spawn to get control of the UGV and move out of the target area. Ideal employment would be to get into UGV, get it out of the target area, get it into defilade, fire and then establish fields of fire.
When the UGV/APD was moving, the enemy was unable to target effectively with RPGs, good self-preservation measure.
Attack scenario—
Blue—civilian truck to get a view of what was going on. The truck was engaged (by AI). Wanted to get behind the prison. There were a lot of prison guards to take down in a short period of time. Tactic was to mow as many bad guys down and get the guards focused on the back side.
Movement in UGV/APD was challenging in terrain. Overestimated the capabilities of the vehicle; perceived obstacles as merely shrubs or small brush rather than something that would inhibit movement.
Red—though the truck was a red asset because it was coming so quickly. Red figured out the way to "win" was to kill prisoners. (**This is gaming this game**)
Red was concerned about blue taking down the back side of the prison to allow prisoners and alternative exit route. Waited around the back. Couldn't see blue team well until they were close.

Wingman?
- Top down view was helpful to coordinate movement. Doesn't think this is a realistic view for controlling unless there is a large antenna to give the "god's eye view" to allow for the easy observation of movement. Potential to mount a camera for visibility.
- Controller and soldier and UGV—player assumed that he had multiple assets. Multi-tasking was not possible. There was no automation to allow for a real "wingman". You don't necessarily get the full wingman concept. Basically perceived it as a packbot or robot that takes the player out of the fight. Player/soldier can't operate the robot and move simultaneously. Couldn't run a scenario where you give the robot direction that "go here, when I click this button, you are going to support by fire from this position while I go to the front gate of the prison." If you could do that it would be more palpable as to the benefit of it. … Avatar needed cover/concealment because they were sucked into the interface of driving, guiding, controlling, shooting, navigating this extra entity.

- Could be a predator operator back in the states … instead of getting shot at could be in a nice comfortable COC.
- We didn't have a squad leader to direct action. Four different guys with their own tool as an extension. They talked through a plan but someone needs to synthesize the action because all players were working independently with their robots. Allows individual to direct others where (who) to engage.
- "Map chip" able to see where your peers are like Blue Force Tracker. Concerned over fratricide and knowing where your friends are. Would like to see where you are going, which way turret was facing in relation to where you are located and where you friendlies are. It took several times to get oriented.
- A turret view might be helpful to show fields of fire. You could extend a "green line" to show range and fields of fire
- Map chip—view limited to simple icons (player provided examples).
- LINK16 SA page—your airplane in center, move cursor over the position of your fellow aircraft and it will give you status (fuel etc.). If they engage, you can see their fields of fire.

Configuration changes for robots?
- Is there a unmanned aircraft system (UAS) realm for the wingman concept? The players were familiar with the Marine Corps' unmanned tactical autonomous control and collaboration system (UTACCS) effort which incorporates both ground and air assets.
- Quadcopter or some small vertical takeoff UAS that helps provide map data. Each ground system will have its own location but could track other moving targets. Depending of foliage, the ground vehicle could lose sight of target and they wouldn't want to "pop out" right in the middle of the enemy.

Armament? Chassis?
- Mission dependent: speed, noise is a factor for covert missions. Size is a factor. Fuel, battery power, power.
- Can it be maintained in a tactical environment?
- If it's just a sensor, it could be pretty small if it's just looking at stuff but not approaching bigger obstacles. But if it's going to be used in mountainous terrain, it would need more power.
- Armor—survive and RPG.
- Looking at prison scenario—if you could flood prison with 4-6 robots and you could bust down gates and fences each armed with a mini gun the increase capability would make it difficult for even 90 bad guys clustered all around. APD was very vulnerable to RPG strike—game over. How would this robot defend itself? What are passive ways to protect it?
- Family of systems—reconnaissance asset the size of a remote control car size, quietly into the bush giving a live feed. The bigger vehicle might need more SA on what it's doing.

APD Chase—family of systems—how would you employ?
- Chase—one asset is unarmed for reconnaissance and it could move fast to be able to get to the area. We were trying to figure out the controls and they were down the road. Armed variants would still be needed. Fast vehicle would be trail vehicle. Armed variants would be out in front so they could engage enemy from the front.
- If the mission was limited to "kill this one bad guy" a mini-gun might not be the best solution.
- One that could call in guided bomb units GBU (guided ordnance). One that is its own claymore—mobile IED.

- Can the person get into the unmanned ground vehicle (UGV) to move from one place to another? (This is not the first time this has been broached by a player.) Person could ride with UGV, get dropped off, push UGV off somewhere else to drive in later to bring firepower. Other players don't like the idea "if there's four bushmaster cannons firing, I don't want to be in a hut in some shantytown."
- Ambush seems like easiest situation to employ—fields of fire of long range high-caliber weapon requires de-confliction of fires.
- De-confliction of fires wasn't an issue but they communicated.
- Slopes were hard to see—the "wiggle" maneuver was used to get up the hill.

What would you do differently with the robot that you wouldn't do with a person?
- Claymore.
- Without being super specific, the willingness to put that vehicle at risk is higher. ... The threshold is much lower.
- In prisoner scenario, put the robot between a few rocks to get concealment and cover. Mine was not really covered and concealed—it didn't take too long for the enemy to train the RPG. If I was a lone Marine I would not have chosen that terrain.

Do you see opportunities for using wingman in any missions?
- Operations we have run over the past 10 years. Why would I run a logistics convoy with 40 people to run a bunch of water bottles?
- Why not run three of these things together with the water bottles, controlled by a guy at the main base of operations? Reduce the risk to the 40 Marines.
- Different ways to extend ISR. It gets fuzzy when you start to combine ISR with offensive capabilities. Challenging to weaponize the assets. See ability to maximize potential for ISR.

Using game environment to discuss wingman? Do you think the game environment is a suitable place to explore ideas?
- Yes, it's repeatable. It's adjustable. It's relatively quick to change, modify. It's less expensive that building these things and taking them out to a range with real bullets, people, etc.
- Incorporating a red force makes it much more realistic. The live red player is critical vice having AI run the red position.
- You could get this out to the troops to start developing TTPs so they get familiar with it.

Do you see this available via web as a viable option?
- Yes, if the asset is actually coming.
- Challenge might be seen if the actual asset is different in the game asset.
- Challenge to incentivize people to play in their own time based on competition with entertainment game.
- People play games on their phones and they buy points to get capabilities to "win" a game.
- Want to build ownership where people will go off to code on their own to get better.

What if time was set aside in a sim center/computer lab on base?
- More practical solution than expecting people to play in their own time.
- If the players get the message that they may be able to impact how something is developed.
- If the product is different than what they were expecting, expectation management would need to be conducted.
- Modification of assets—being able to mod by changing engine and other features.

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- For demographic—needs to be seamless because the interest level wouldn't be sufficient to get the player to learn how to employ something way different on a keyboard.

What is PMs were able to get this out there for people to provide input?
- Flash to bang—will this impact me in my career or will it come out in the far future?
- Uncertain about the length of the acquisition process
- Example—have unit play, give feedback, return a week later and new capability is present.
- Concern expressed over the change provided not matching what they were really looking for. Users may not be satisfied because what was provided didn't really match what they were looking for.
- If there are 18 suggestions, pick the top 2 (or whatever) and check the changes out a month later and refine what's provided. Constant development refinement rather than you are stuck with what you have. Developmental input would matter along the way but for fielding, "packaging is important"
- Here was our original solution—we had 1000 people play and provide input and we got the top X inputs. We couldn't take all ideas. "my idea didn't fare so well" but the other ideas were addressed and maybe my idea no longer makes sense or maybe it will be incorporated in the future.

APPENDIX L. SUMMARY TRANSCRIPTION OF POST-GAME INTERVIEW (SESSION 4)

Group 4
Red wasn't sure about the blue Toyota
Prison attack—like it best because it was the most realistic (and blue won!).
Defend—re-spawn was not ideal.
Blue plan—get high ground to get observation on the prison. Left APDs and took trucks. The APD blew up. Players were able to stay alive long enough in the hills.
Red plan—went outside of the prison because they knew they were coming from the north. For the second attempt they stayed closer to the prison.
They thought it was more realistic to not know exactly where you were located. Don't think that some of the games for entertainment are based in realism—they give instantaneous feedback on location.
Felt disoriented; tried to match terrain to the map rather than have location information handed to you.
For red, no indicator that RPG was actually loaded by graphics.
Indicator for turret would be helpful. Like in an LAV, 2 rings.
Immediately turn off safety in game—this might teach bad habits for real life. Muscle memory in real life allows for rapid transition. If there is no value to the game, disregard having safety on.
What do you think of wingman? Do you think it's useful to have a robot?
- Depends on scenario and what kind of robot.
- Need 3 people. Need someone to control the robot and two others to provide overwatch for the robot because the controller gets sucked in on the robot.
- One problem in the game, went on to the roof and got into the prone. But once APD controller used, avatar stood up revealing player and then he got killed.
- Use a robot to send across a danger area first. Or, provide overwatch from an area where you don't want to send Marines.

Scenarios for robots?
- Defense.
- Attack—there are too many audibles.
- We wouldn't drop 1-2 guys with a robot—not realistic.
- If the robot dies it's not a Marine.
- Keep the human somewhere else within the control range of the robot.
- If course of action (COA) is to drop LCpl Banatz behind EN lines with a robot – NOT realistic.
- Useful for urban terrain for MOUT. Awesome to be able to put robots places you don't want to send Marines.
- But how much gear do you want to hump?
- Like in Mojave Viper, you get packbots and need to incorporate them into the scheme.
- Humping another weapon, ammo, batteries. … Just throw in the back of a truck.
- But if you're working with tanks to support infantry. But if there aren't enough tanks, you could employ this as an alternative with slightly different objective—down small allies or into buildings.
- How far forward can you push a robot?

- Can the robot do something that you wouldn't get by support by fire—we already have precision support by fire—GPS artillery rounds. Counter was that this is actually a direct fire weapon.
- If player is moving, he can't control the robot so it's not really a wingman, it's an extension.
- Imagine you are clearing a sector of a city, you could use it like tank and infantry integration. But, to counter, the logistical requirements to support the tanks (fuel, water, mechs). But what other gear do you need? Fuel, batteries.
- Brings firepower, armor.
- Can we blow in place if it is dead in the water?
- Defense.
- Gun truck— .50 cal in the fight where you might not have had one previously. Rather than a high mobility multi-purpose wheeled vehicle (HMMWV) with a .50cal you have a robot. T72 is automated reload - concern about weapon jams—gun-truck is out of the fight.

Armament?
- Hesitant to put a MK19. Jamming, ROE considerations—only appropriate for full spectrum. Or, like a track— .50cal and MK19 together.
- Fields of fire a concern for chase but not for the other scenarios.
- Would need to develop an institutional change—it's a robot, if it gets shot, it gets shot.
- A UAV currently gets treated "like a person" because it's an important asset. Recovery of UAV is prioritized.
- Tactical control measures applied. Gravity of situation determines the amount of risk you want to take. But if it's a gnarly situation it will be easier to put a robot into the fight.
- What is the interaction: laptop or full heads up display full immersion?
    o Two people—one person driving and one manning turret.
    o Or, have controllers back in "vegas" with more specific controls. Having a heads up display where you turned your head would make it a useful technology. Security would not be an issue.
    o Or, push controls as far forward as possible. Local security is important. Questions ability to integrate a heavy weapon into the scheme of maneuver without being able to physically reach out and tough the controller.
    o Counter—no different than controlling support by fire over radio.
    o Must take into account the additional security requirement for additional people in the headquarters (HQ) or a fire support team (FST).

Trial and error—where locate, how to employ assets? ESP to develop ideas?
- Good because you don't have the overhead of going to the field and lock on all logistical support requirements.
- Need to make it as realistic as possible.
- Integrate into a mission for a squad or platoon.
- Can APD be manually controlled if all other controls fail?
    o Could the person control it?

Customization option?
- VBS2 – can it be modified by players?
- Have squad leader or platoon leader to "fight" the scenario. Have a Marine or two be the OPFOR
- Who is saying these need to be armed? I'm terrified of robots with guns.
- If you take the weaponry on, it will be smaller, lighter, and require less logistics load.
- Why arm it in the first place? I would be concerned about a Marine getting run over.

- Employ like a mobile strong point—a Marine is then gunning it. Not relying on the system sensors. Something that drives up and deploys into a twin gun section. Why employ it like a tank at all? Small wheeled or tracked asset (like the mules that carry packs). The position could aid with bounding overwatch—this is like a transformer. It carries your weapons and armor
- Breaching, smash through walls.
- Terrified of rules of engagement (ROE) with robots on the battlefield.

What conclusions do you think we cannot draw?
- Size was a challenge from IED robot size to HMMWV.
- Personal security requirements of operator and how to integrate the operator into the unit.
- Logistics requirements.

Do you think ESP is practical for the future?
- Need to establish incentive to play.
- Each Marine Expeditionary Force (MEF) could send an independent augment for a month—they get good with the controls and cycle through to test and evaluation. Becomes a MEF think tank for the MEF. Short timers—guys with EASs coming up that you don't want to incorporate mainstream in the unit.

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APPENDIX M. SUMMARY TRANSCRIPTION OF POST-GAME INTERVIEW (SESSION 5)

Group 5

Wingman—separation between reality and the game.

See the advantage of having the robot at the prison.

One vehicle was in support by fire position, Red team ran out of the prison to be slightly more offensive. Doubted his ability to hit the APD with an RPG—the APD was headed to the game taking people down.

Red—couldn't use the RPGs in the guard tower because the tower was enclosed and there were people close by. Thought he was observed in a guard tower but had several opportunities to shoot. Red realized that the APD couldn't hear or see anything.

** While robot is out in an environment, it can't "hear."

Near miss indicator? May or may not be realistic; camera on the periphery to be able to see left and right if there was a round impacting nearby. Since Red had the opportunity to shoot several times without the APD moving, it was obvious to the Red player that the APD operator didn't know that the robot was being engaged.

Robot is an extension of the player but it doesn't have the same senses as a person.

Other scenarios?

- From a real life perspective. A lot can go wrong with the robot out there.
- IT was pretty easy to move the robot around on the terrain, perception that it wouldn't be that easy in the real world.
- You are more removed from the scenario. People in video games can be pretty ruthless because they don't care. Players are more aggressive, less risk averse. Moral and ethical concerns.
- Games for entertainment vs. games for training—need to input constraints to encourage risk but not manipulate players' inputs beyond reasonable courses of action (COA).
- Player rated his own performance as over-aggressive.
- User of robots: if integrated in with other forces, rather than pure robots or pure human forces. Two robots are out there on their own and one is down—need to do a TRAP to recover it or self-destruct it.
- Advantage seen as integrated into unit. Example: company size element to secure a prison. Emplacing robots in high ground in support by fire positions. Having personnel come in behind the assets once threat level reduce to a more acceptable level. This would reduce threat to a more acceptable level. The controllers would be co-located with the company fire support coordination center or with a Fire Support Team. The commander would then be able to direct vehicles to particular positions to have fires directed at a particular target location.
- Wingman—a section is two vehicles. One vehicle be human operated and one be the UGV controlled by someone sitting in the manned vehicle. This is basically "doubling assets" without doubling number of people endangered in the scenario.

How would you change the firepower, armament, mobility?

- Concerns over remotely controlling a vehicle in a combat zone.
- Tracked vehicles.
- Running into trees and rocks—what kind of damage is occurring? Can damage be built into the models to account for how someone is driving and how terrain actually impacts the vehicle? What

is a normal level of damage or wear and tear for different terrain? What about an unskilled operator—how much worse is the damage?

Armor—group expressed concern over vulnerability to RPG

- Mix of armament vs. mobility will be situational dependent. If supporting tanks against other tanks, would need heavier armor. If running light scout, need more sensor, lighter armor, higher mobility. Without troop quarters, additional armor can be incorporated without added to weight of the system. Need to address weight and opportunities to self-recover—like throwing track or losing wheel.

What do you prefer lots of light-armored robots or fewer survivable assets?

- Light armored guys want more light assets (really wants medium).
- Seen as more a tool for reconnaissance, to gather imagery. Tend toward lighter.
- Some players would rather heavy because they don't trust the imagery for ISR. And, thinking of how soldiers would treat equipment. Asset needs to be robust to abuse and use. If light asset could be robust to use and user abuse then it might be an option.
- "Loaded question."

How would you employ a robot considering risks?

- If there is an extremely dangerous scenario where you can prevent putting a human being in that harm and use the robot to clear the way before they enter. Assault breaching vehicle comparison to proof a lane and have unit/forces that fall in behind the cleared route.

Concerns?

- Situational awareness. Like the idea of sound.
- Marine Corps is more likely to support infantry—having ground forces able to shout and have the operator hear the interaction and make adjustments.
- The operator is in theatre, in the area of operations (AO). Not in Nevada because they lose connectivity to the fighting environment. Prefer with the commander on the ground who is directing forces.

ESP—is a game environment a suitable place to be experimenting with ideas like this?

- Cost effective way to do it.
- Controlled live environment to test it in concert with the game environment.
- Concerns about the physics of the environment.
- This is a good forum for brainstorming new ideas!
- What do you wish you had? I wanted a widget like this … and then, be able to try it out and see if it is practical or not.
- This is preferable than taking all the "good idea fairy" ideas and making physical prototypes.
- Testing environment to determine what is viable for physical testing.

What do you think you can't draw from the game environment?

- Situational awareness.
- Physics.
- Damage.
- Natural friction that goes along with actually going out and performing a mission.
    - Crypto goes down.
    - Controller isn't interfacing with vehicle.
    - Deadline pressures of mission requirements.

- o Being able to proceed with/without.
- o Perspective of enemy—how it impacts their OODA loop. Do they adjust their tactics? Red would be intimidated that robots were coming at them rather than real live people.
  - ▪ Possible mitigation is to bring live red players.

Do you think you, your Marines, can have an impact on future development?
- If the people that make decisions are open minded and buy-in to a technique like this.

Analysis of Alternative—scope down to comparison
- Option for PM—there is merit.
- This is a different method of conducting simulation: constraints, limitations, assumptions.
- Command needs buy-in for how evaluation is conducted.

Buy-in a lower levels—taking soldiers/Marines to sim centers
- o Part of broader study.
- o Competing demands—programming time to assist with an effort.
- o Marine Corps Warfighting Lab (MCWL)—experimental division, think tank, having better representation in an organization like that. Or, another option is augmenting with units when they are on a down-side of training schedule.

Home play?
- I don't think players would play at home without significant incentive due to challenge to compete with commercial gaming options.
- If you can download VBS2 light at home—not sure how to collect metrics.
- Think that unit participation is more likely.
- What are you doing to incentivize individuals to play? Points on AKO or USMC site to reward their participation.
- Part of training package—schedule rather than an add-on for a unit to jump on.
- Incentive piece—more realistic usually means less fun. How to grow individual motivation to participate?
- If soldiers were to play and see a return—the turn around is the challenge. A private might see their effort when they reach the rank of general—the immediate feedback.
- IDEA from previous group—top 20 recommendations published so that soldiers could see their ideas.
- Maybe warfighting lab brings people to Quantico to help with their ideas if they are good players—this is a challenge with anonymity. Maybe they can opt out if they don't want to partake.

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